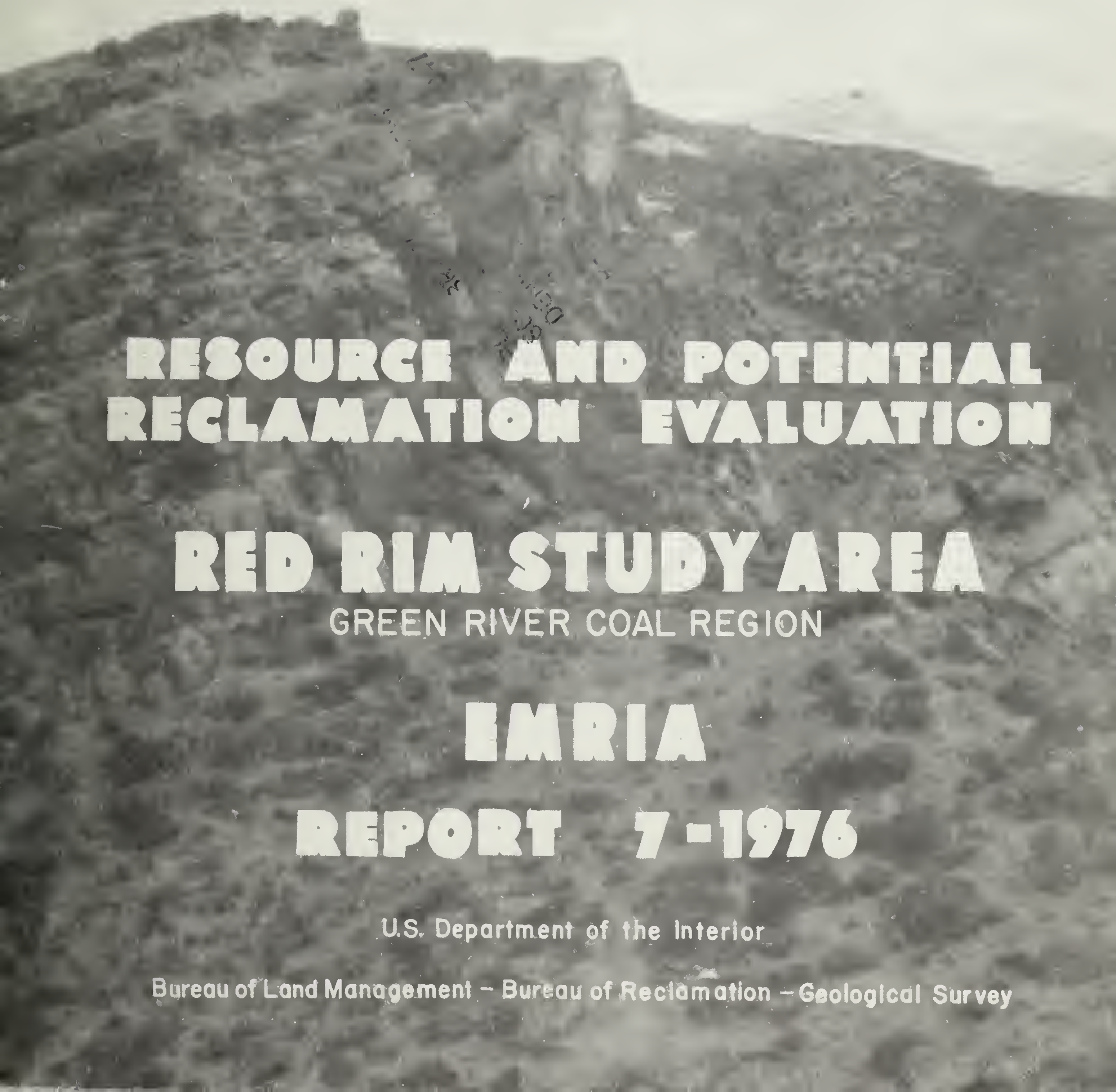

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RED RIM STUDY AREA

GREEN RIVER COAL REGION

EMRIA

REPORT 7-1976

U.S. Department of the Interior

Bureau of Land Management – Bureau of Reclamation – Geological Survey

EMRIA - Energy Mineral Rehabilitation Inventory and Analysis

The purpose of the EMRIA program is to provide information on the reclamation potential of lands under consideration for mineral development or other major land disturbing activities.

The objective of Reclamation Study Area Reports is to provide the information needed (in addition to existing information) to enable management officials to determine 1) can the area be effectively reclaimed, 2) what are the major problems involved in reclaiming the site, and 3) what measures would be necessary to establish conditions suitable for the intended post mining use.

These reports are prepared through the efforts of the Department of the Interior principally by the Bureau of Land Management, Bureau of Reclamation and Geological Survey. Assistance is also provided by other Federal and State agencies.

Reports under this effort are:

EMRIA Report	Location	Source - BLM Offices
#1 - 1975	Otter Creek near Ashland, Montana	Montana State Office Federal Building 316 N. 26th Street Billings, Montana 59101
#2 - 1975	Hanna Basin near Hanna, Wyoming	District Office 1300 Third Street P.O. Box 670 Rawlins, Wyoming 82301
#3 - 1975	Taylor Creek near Craig, Colorado	Colorado State Office 1600 Broadway - Room 700 Denver, Colorado 80202
#4 - 1975	Alton near Kanab, Utah	Utah State Office Federal Building 125 South State Street P.O. Box 11505 Salt Lake City, Utah 84111
#5 - 1976	Bisti West near Bisti, New Mexico	New Mexico State Office Federal Building P.O. Box 1449 Santa Fe, New Mexico 87501
#6 - 1976	Foidel Creek near Steamboat Springs, Colorado	Colorado State Office 1600 Broadway - Room 700 Denver, Colroado 80202
#7 - 1976	Red Rim near Rawlins, Wyoming	Wyoming State Office 2120 Capitol Avenue P.O. Box 1828 Cheyenne, Wyoming 82001
#8 - 1976	Bear Creek near Ashland,	Montana State Office 222 N. 32nd Street P.O. Box 30157 Billings, Montana 59107
#9 - 1976	Horse Nose Butte, near Manning, North Dakota	Montana State Office 222 N. 32nd Street P.O. Box 30157 Billings, Montana 59107

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PHOTOGRAPHS (Con.)

INTRODUCTION

A growing and affluent society is creating an ever increasing need for energy. Attention has focused on the energy fuels and sources existent in the western States, primarily the Rocky Mountain and the Northern Great Plains Coal Provinces due to the abundance, simplicity of extraction, and the high quality of the resources present.

It is the responsibility of the Bureau of Land Management to encourage and assist in meeting these energy demands and at the same time assure sound reclamation so that the disturbed lands are returned to a productive and useful state.

Purpose

The main purpose of this study is to determine the reclamation potential, the problems that would be involved in reclaiming the area, the measures that would be required to establish satisfactory conditions.

Objectives

The overall objectives of the Energy Minerals Resource Inventory and Analysis (EMRIA) program are as follows;

1. To evaluate environmental effects of surface mining of areas under consideration for coal development.

2. To provide resource and impact information for the leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource and reclamation information needed for development of effective lease stipulations as required by the mined land reclamation program.

4. To provide resource, impact, and reclamation information to support State and local regional development and land use planning efforts.

5. To determine the present and potential capability of the surface soil and subsurface resources to support vegetation on known energy fuel deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for energy mineral exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of Technical Examination, Environmental Analysis Records, Environmental Impact Statements, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study.

Authority

Public Land Administration Act of July 14, 1969 (74 Stat. 506).

Responsibility

The following agencies were involved in the study.

Bureau of Land Management

1. Select reclamation study areas for coordinated investigation of vegetation, soil geological structure, surface water, and ground water.

2. Prepare coordination, issue and monitor the execution of work orders.

3. Review and consolidate work order and field office data and prepare input to reports published by the Bureau of Reclamation.

4. Procure easements and rights-of-way to conduct the studies.

5. Distribute technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

Bureau of Reclamation

1. Conduct land studies, including a land classification, soil survey, and laboratory characterization program.

2. Conducts drilling operations for the procurement of core samples to be used for the analysis of geological strata in overburden materials.

3. Map surface geology.

4. Prepare geologic logs on drill holes.

5. Collect coal samples.

6. Installs casing in holes selected for ground water observation wells.

7. Characterizes and interprets data available on soils and overburden materials as well as substrata immediately below the coal resources in relation to reclamation and revegetation.

8. Advises and recommends suitable plant species for use in areas to be reclaimed.

9. Advises and recommends reclamation techniques.

10. Coordinate, assembly, and printing of final report.

Geological Survey

1. Conduct vegetation and soil studies which will result in vegetation maps and related hydrologic properties of soils.

2. Assess reclamation potential based on water availablity.

3. Prepare sediment yield maps.

4. Prepare erodability illustrations.

5. Determine rainfall-runoff relationships and analyze surface and subsurface waters for chemical quality.

6. Coal sections and well logs.

7. Coal bed maps showing coal resources.

8. Tabulation of coal resources estimates.

9. Table of analytical results on coal resources.

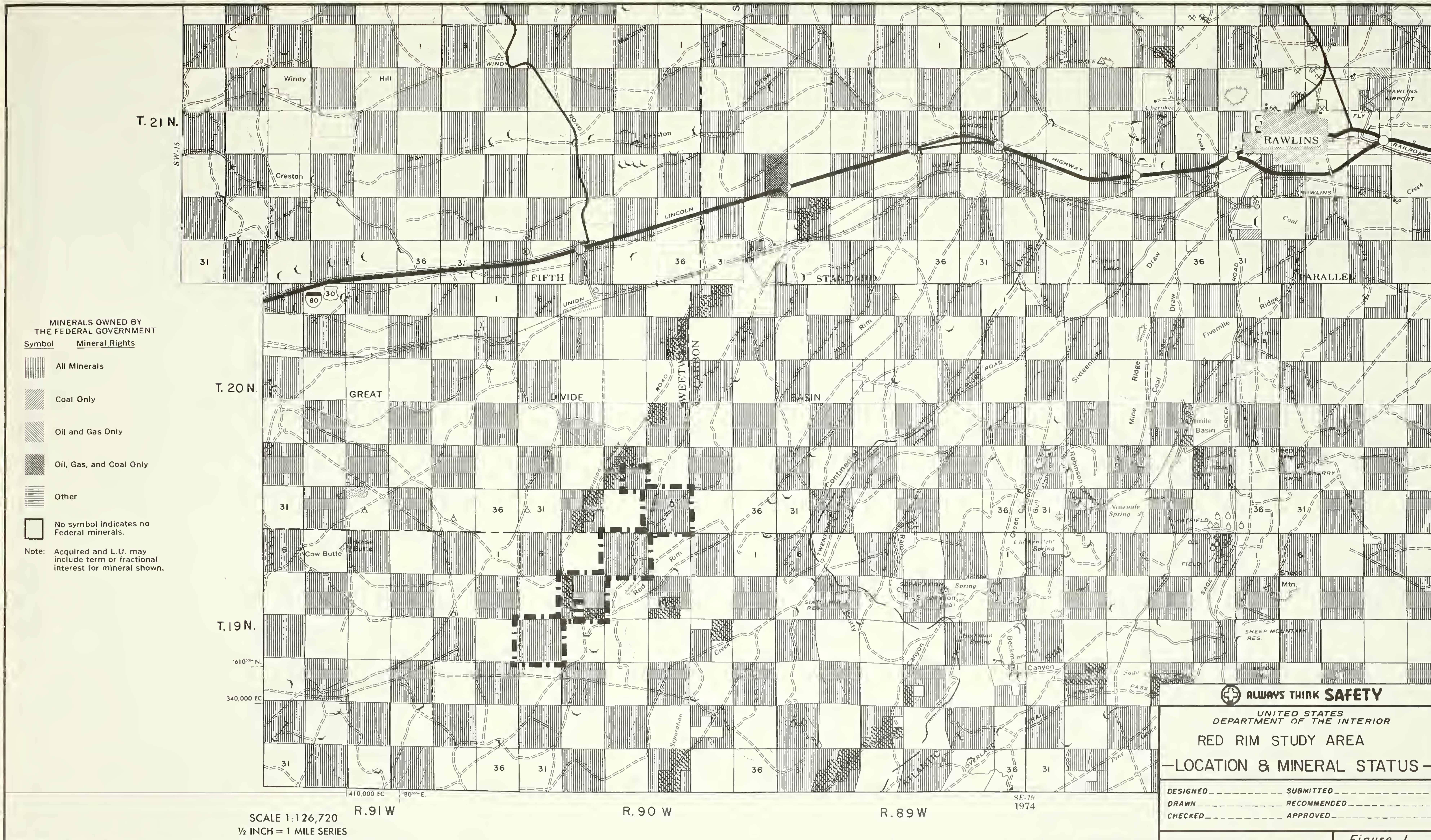
10. Graphic presentation of analytical results.
    a. Vertical - Plotted against well logs.
    b. Horizontal - Plan view if significant.

11. Evaluation of the effects of mining on the area hydrology and downstream.

Location and Setting

The area under consideration, referred to as the "Red Rim" reclamation study area is located approximately 15 miles southwest of Rawlins. The lands being studied lie within the Carbon and Sweetwater Counties described as follows:

T. 20 N., R. 90 W.	T. 19 N., R. 90 W.
sec. 28: SE¼	sec. 4: All
sec. 34: All	sec. 8: N½, W½SW¼, SE¼
	sec. 18: All


MINERALS OWNED BY THE FEDERAL GOVERNMENT
Symbol
Mineral Rights
All Minerals
Coal Only
Oil and Gas Only
Oil, Gas, and Coal Only
Other
No symbol indicates no Federal minerals.
Note: Acquired and L.U. may include term or fractional interest for mineral shown.
T. 21 N.
T. 20 N.
T. 19 N.
R. 91 W
R. 90 W
R. 89 W
SCALE 1:126,720
½ INCH = 1 MILE SERIES
RAWLINS
Windy
Hill
Creston
GREAT
DIVIDE
BASIN
FIFTH
STANDARD
PARALLEL
LINCOLN
HIGHWAY
Cow Butte
Horse Butte
Red
Rim
Hatfield
Oil
Field
Sheep Mtn.
SHEEP MOUNTAIN RES
SE-19
1974
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
RED RIM STUDY AREA
—LOCATION & MINERAL STATUS—
DESIGNED
SUBMITTED
DRAWN
RECOMMENDED
CHECKED
APPROVED
Figure 1

Land ownership is in a checkerboard pattern as a result of the grant of alternate sections to Union Pacific Railroad within a 20 mile limit both sides of the right-of-way. The Bureau of Land Management administers the surface and all the minerals in the reclamation study area.

The communities of Rawlins, Sinclair, and Wamsutter are located north along Interstate Highway 80.

Major highways in the area are Interstate 80 and State Highway 789 south of Creston Junction. County road, twenty-mile road south of Rawlins along with undeveloped trail roads, make up the remaining road system.

Separation Creek is the major drainage in the area.

The area is characterized by numerous short draws and sandstone outcroppings originating from Red Rim and feeding into long meandering draws which traverse the rolling to flat terrain.

Brief Historic Summary

There is evidence of early man in this area. Modern man used the Overland Trail which lies south of this area as a major transportation system in the migration westward. The land has been used primarily for livestock grazing, ranching, mineral exploration and development, hunting and recreation.

CULTURAL RESOURCES

Archeological

There are 41 known sites within the Red Rim mining area threatened with complete or partial physical destruction if mining occurs. Those which do not meet the criteria for inclusion in the National Register would be excavated or salvaged. An indeterminate amount of archeological information would be lost by removing the cultural materials from their original context and destroying the site locations.

Historical

No resources have been located within the lease area; however, this does not discount the possibility of historical resources being located in the future during intensive cultural surveys.

Biological Resources

Wildlife

Pronghorn Antelope

A cursory examination of the 4½ sections of national resource lands was performed on June 8, 1976. The topography of Red Rim ranged from moderate cliffs and rims to rolling hills in the adjacent areas. The major big game animal species in the area is pronghorn antelope, which depend on big sagebrush for survival. The rough physical features of the countryside provide ideal year long habitat for pronghorn. The draws contain sagebrush heights desirable for fawning areas and are used extensively for this purpose.

The area provides the daily forage requirement of 3.5 pounds per animal for antelope during the winter season. The area should rate good for winter, spring, and summer-fall seasons according to the Big Game Habitat Condition Rating Criteria as shown in the appendix.

The draw beginning in the eastern edge of section 4 and extending northward through section 34 was receiving a high degree of use by solitary doe antelope during the time of examination. Fawns were present in the area. These factors indicate the sections of concern and provide an important area for antelope fawning, a basic life function which is critical to the perpetuation of the species. The area described must be classified as a crucial antelope fawning area as well as an area which provides other basic life requirements for antelope.

Mule Deers

The ridgetops and slopes along Red Rim and the slopes to the west contain an abundance of browse plants for wintering mule deer. The major species of browse are bitterbrush, rabbitbrush, mountain mahogany, and sagebrush. A browse utilization transect was completed within the area on June 25, 1976. Results show mountain mahogany comprising 50 percent of the browse stand and receiving 59 percent utilization. Bitterbrush makes up only 12 percent of the browse stand but receives 57 percent utilization. The age class of the browse stand shows 90 percent mature plants with some young and some dead plants, an indication of a healthy browse stand. The form class does not indicate overuse. Pellet group counts show 27.7 animal days per acre for mule deer and 13.8 animal days per acre for antelope.

These figures indicate a fair number of deer making fairly heavy use on a limited amount of browse. The browse plants that are present are extremely important to the deer using the area due to the limited extent of the browse stand. The browse covered ridge tops and slopes

provide crucial winter habitat for the mule deer present. Additional field evaluations will be necessary to rate the area for mule deer habitat, according to the Big Game Habitat Condition Rating Criteria shown in appendix F.

Raptors

The cliffs along Red Rim provide numerous nesting sites for several species of raptors. Active nests were observed along the rim during the field examination. The rim appears to contain several historic raptor nesting sites, particularly for falcons and eagles, although other raptor species are surely present. The surrounding stream bottoms and rolling prairie provide ample hunting opportunities for several species of raptors in the area. The cliffs along Red Rim provide nesting habitat which is critical in the life cycle of the raptors using the area. Therefore, the cliffs must be considered as crucial nesting habitat for raptors.

Visual Resources

The Visual Resource Management Analysis for the region which includes the Red Rim Study Area evaluates the area as having low scenic qualities. It is located in a visual background zone as observed from the primary travel routes (Interstate 80 and Wyoming State Highway 789). Located just west of Red Rim proper, the study area's topography consists primarily of rolling hills dissected by intermittent drainages. However, a brief examination on June 8, 1976 of National Resource Lands in the area indicate that the topographic relief of the Red Rim proper (just east and adjacent to the study area) possesses striking scenic variety. This variety is expressed by moderate cliffs and rims broken up by sloping alluvial drainages to the east. The Rim's white, red, and brown sandstone outcroppings highlights an appealing visual contrast. but cannot be considered exceptional in comparison to other areas in the region.

Present recreational activities in the area consists primarily of big game hunting and possibly off-road vehicle use. The checkerboard land ownership pattern and general topographic nature of the study area does not make it well suited for extensive off-road vehicular use.

Climate

The climate in the Red Rim area is classified as semi-arid (Wesche and Shinner 1973). Deep cold air masses from Canada occasionally invade from the northwest and characteristically turn eastward while shallow cold air masses rarely reach the area. The predominant air masses from the Pacific coast deposit most of their moisture over the mountain ranges in western Wyoming while air masses from the Gulf of Mexico seldom reach as far north as Wyoming.

The nearest weather station is in Rawlins, 400 feet lower in elevation and approximately 15 miles to the northeast of the study area.

Temperature

Temperatures at Rawlins are normal relative to the elevation gradient and are representative of the study area. The mean annual temperature at Rawlins is 43 degrees F. The mean monthly temperature (F) are as follows:

January	22	May	50	September	56
February	24	June	61	October	44
March	30	July	68	November	32
April	41	August	66	December	24

A graph of the highest maximum and lowest minimum monthly temperatures and mean for the Rawlins airport and maximum mean and minimum mean monthly temperatures is presented in Figure 2.

The growing season for establishing grasses on mine spoils is approximately 70 to 80 days. This was estimated by the time between the date that mean monthly minimum temeratures exceed 28^{o}F (approximately the first week of April) and the date potential evapotranspiration is greater than available moisture (about the middle of June). Mean monthly temperatures at Rawlins were used and adjusted to the study area by the factor of a decrease in temperature of 5^{o}F per 1,000 feet increase in elevation.

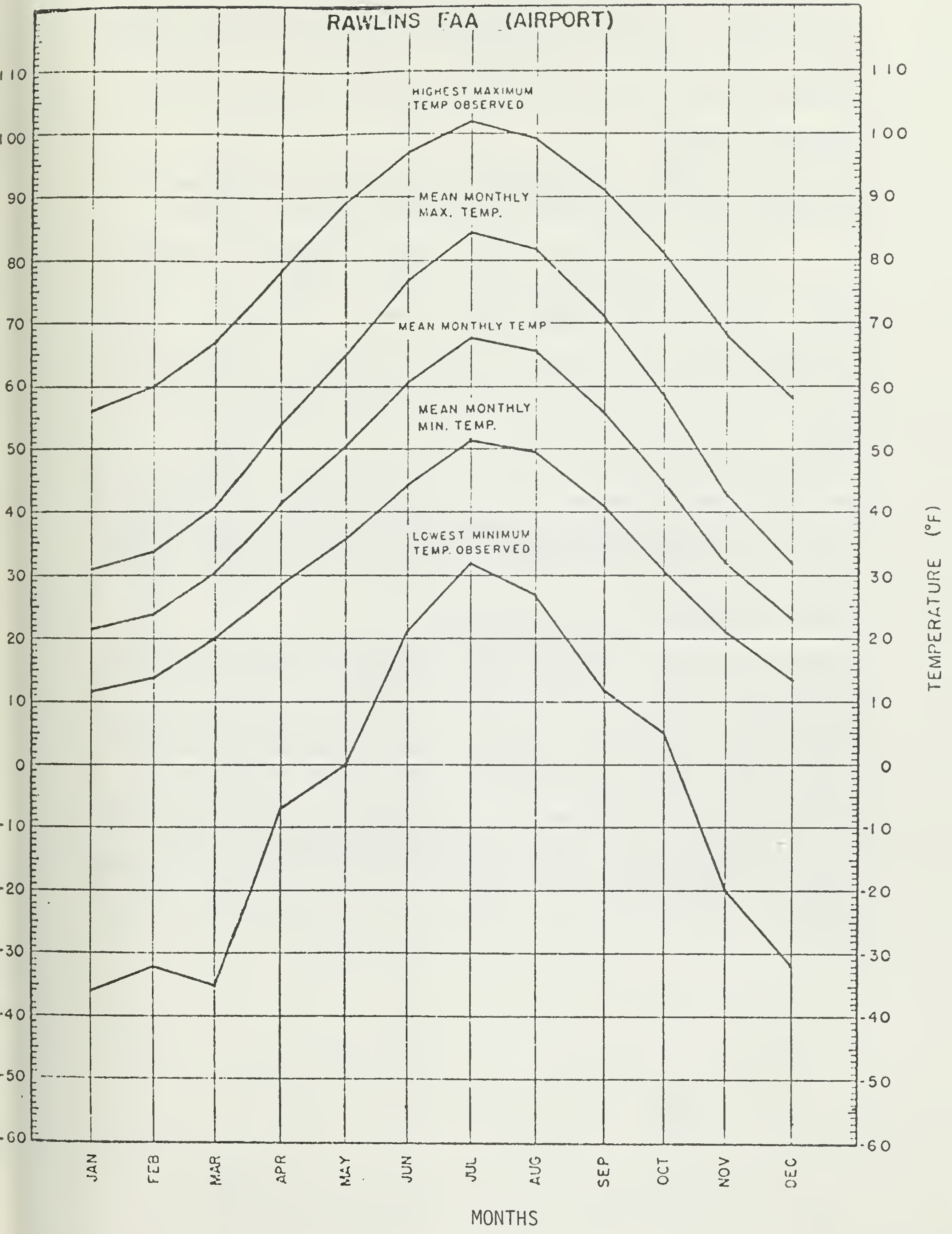
Precipitation

Mean annual precipitation at Rawlins is 10.43 inches with the highest annual total of 11.72 inches occurring in 1965 and the lowest annual precipitation of 4.9 inches occurring in 1954. Average precipitation is as follows:

January - March	April - June	July - September	October - December
Snow	Snow and Rain	Rain	Snow
2.26 inches	3.40 inches	2.59 inches	2.18 inches
22 percent	32 percent	25 percent	21 percent

As can be seen, the greatest amount of precipitation occurs in spring and early summer. The winter months of October to March average less than 0.6 inches per month. The mean annual snowfall at Rawlins is

Figure 2.


RAWLINS FAA (AIRPORT)
HIGHEST MAXIMUM TEMP OBSERVED
MEAN MONTHLY MAX. TEMP.
MEAN MONTHLY TEMP
MEAN MONTHLY MIN. TEMP.
LOWEST MINIMUM TEMP. OBSERVED
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
TEMPERATURE (°F)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTHS

42 inches and contributes approximately 40 percent of the annual precipitation. During the summer months showers are fairly frequent, however, they are rather light and often amount to a few hundredths of an inch. Occasionally there will be some very heavy rain associated with local thunderstorms covering a few square miles.

Evapotranspiration

Evapotranspiration, as estimated using the Blaney-Criddle method, for grass lands and mean monthly precipitation are as follows:

	April	May	June	July	August	September	October
E.T.	1.11	3.64	5.46	6.54	5.40	3.11	1.32
Prec.	1.07	1.43	.90	.87	.76	.96	.98

The above figures show that soil moisture becomes limited in June and soil moisture deficits increase throughout the summer months.

Wind

The winds at Rawlins are predominantly (45 percent of the time) from the west-southwest (Table 1). The winds are calm 23 percent of the time and the wind speed (4.26 percent of the time) is greater than 25 mph. The winds have a higher average velocity in winter (17 mph) than in summer (10 mph) with an annual average of 14 mph.

Effect of Weather in Site Revegetation

Climatic factors will have an adverse effect on revegetation of the Red Rim study area. The most important weather related factor influencing reclamation techniques and procedures are the low precipitation, high wind velocities, and the resulting high potential evapotranspiration rates. The winter winds redistribute the snow leaving many areas bare. Where the snow has been removed among recently established vegetation, large amounts of winterkill occur. Soil movement caused by the wind also damages and kills vegetation by its abrasive action. Because of greater amounts of incoming solar radiation and dry westerly winds, south and west facing slopes tend to be more droughty than north and east facing slopes. The result is an unfavorable environment for seed germination and plant growth.

TABLE 1.

ANNUAL PERCENT FREQUENCY OF WIND SPEED AND DIRECTION

RAWLINS, WYOMING
(1960-1964)

Direction	Speed Groups in MPH 0-5	6-12	13-15	16-24	25-31	32-38	39 & Greater	Total
N	.15	1.38	.28	.42	.03			2.26
NNE	.04	.70	.19	.32	.01			1.26
NE	.12	1.72	.44	.71	.04	.002		3.03
ENE	.09	1.31	.33	.60	.02			2.35
E	.11	1.14	.23	.35	.02			1.84
ESE	.07	.49	.05	.07	.002			.69
SE	.05	.50	.04	.05				.65
SSE	.03	.19	.04	.04	.002			.30
S	.09	.62	.11	.23	.01			1.06
SSW	.04	.78	.26	.89	.16	.04	.002	2.17
SW	.22	6.03	2.21	7.84	1.22	.31	.06	17.90
WSW	.25	8.92	3.95	12.29	1.43	.33	.02	27.19
W	.12	3.62	1.31	3.97	0.36	.05	.01	9.44
WNW	.07	1.16	.41	1.15	.09	.01		2.88
NW	.16	1.58	.28	.40	.02	.005		2.44
NNW	.10	1.01	.12	.22	.02			1.45
CALM	23.07							23.07
TOTAL FREQUENCY	10825	13606	4464	12914	1500	325	38	
PERCENT	24.79	31.5	10.22	29.57	3.43	.74	.09	100.00

PHYSICAL PROFILE

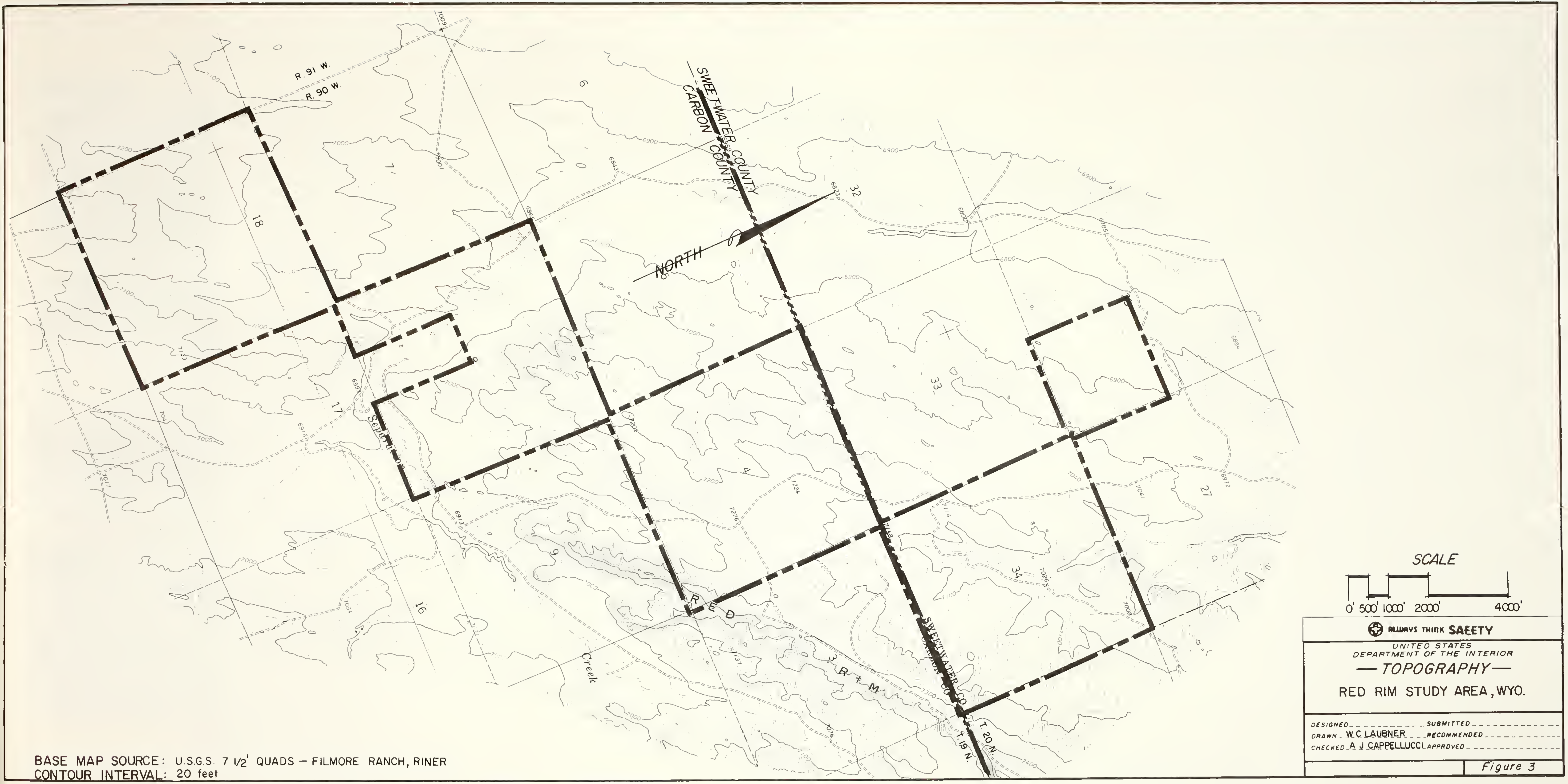
Topography

The Red Rim area is located in southcentral Wyoming on the south flank of the Wamsutter Arch (Sanders, 1974). The arch, an indistinct structural feature, acts as an east-west divide between the Great Divide Basin to the north and the Washakie Basin to the south. The Red Rim study area is located in the extreme southeastern part of the Great Divide Basin. This basin, approximately 75 miles from east to west and 50 miles from north to south, is bounded by the Ferris Mountains and Antelope Hills on the north, Seminoe Mountains on the northeast, the Rock Springs uplift on the west, and by minor uplifts and lessor mountain ranges encompassing the remaining perimeter. The southern section of the Great Divide Basin is known as the Red Desert, so called due to its aridity and the red surface coloration of soils of the area.

The Red Rim area is typical of semi-arid rolling to rugged high plains. The uplands are incised by numerous draws and small valleys tributary to the major drainage known as Separation Creek, normally flowing for only short durations, primarily during the period of spring snowmelt. General topography varies from gently sloping to steeply sloping. The alluvial fans which adjoin the narrow floodplain of Separation Creek are gently sloping, with slopes of three percent being dominant. Between the uplands and Separation Creek are numerous narrow valleys of moderate slope. On the leeward side of Red Rim and other southwest-northeast ridges east of Separation Creek, the topography is both irregular and rough. This is due to a combination of aeolian sand deposition on north and east slopes which break into the fairly steep drainageways. Drainages within the landscapes dominated by sandstone ridges are normally more U-shaped in cross section than are the drainages originating from uplands underlain by medium textured siltstones and soft shales.

Elevations in the Great Divide Basin range from 6,400 to above 9,200 feet, with Whiskey Peak on the northern most edge of the basin, rising to 9,225 feet above sea level. By comparison the elevations reach over 10,000 feet in the Wind River Range north of and over 12,000 feet in the Park Range south of the Great Divide Basin. The Red Rim study area, approximately 2,600 acres in size, has elevations ranging from 6,800 to 7,340 feet. The town of Rawlins, Wyoming, which is approximately 15 miles northeast of the study area, has an elevation of 6,775 feet.

The geology has played an important role in the relief and landforms of the study area. Narrow ridge crests with steep side slopes and escarpments dominate the uppermost landscapes. These areas contain a sizable portion of exposed sandstone and siltstone. The red sandstone Red Rim escarpment and the associated ledges are the most striking feature of the area.



UNITED STATES DEPARTMENT OF THE INTERIOR

— TOPOGRAPHY —

RED RIM STUDY AREA, WYO.

Figure 3

Geology

Regional Geology

The Great Divide Basin is a hydrographically closed structural basin. Due to low annual rainfall and high evapotranspiration rates, the Great Divide Basin has no outlet and consequently waters from the area never reach the sea (Fenneman, 1931).

Underlying the Great Divide Basin are thick sequences of sedimentary deposits. These sediments have produced uranium, oil, gas, and coal from various scattered locations within the basin. Structural relief between Precambrian rocks beneath this basin and the same rocks in the mountains to the north of the basin are on the order of 26,000 feet (Thornbury, 1965).

To the southeast of the Great Divide Basin is a line of uplifts marked by the Rawlins uplift, Hatfield Dome, Miller Hill-Lake Valley anticline, and Espy anticline. These uplifts have given strata in the study area a homoclinal northwest dip (Sanders, 1974). The dip, combined with differential weathering, has given rise to a belt of dissected cuestas and hogbacks in the vicinity of the study area.

Site Geology and Stratigraphy

The Red Rim area is located on the south flank of a broad low structure known as the Wamsutter Arch. Dips of the formations within the project area range from 24 degrees in some places along the Red Rim to 11 degrees in the area adjacent to Separation Creek. Generally, slopes within the study area tend to be slightly less steep than the dips of the underlying strata but become much steeper in drainages. Surface expressions of underlying structure in the study area tend to follow the strike of the strata. The strike of beds of the Fort Union and Lance Formations are northeast-southwest and beds have a homoclinal northwest dip.

Areas of very high relief (breaks) and very low relief may be found in section 4, T. 19 N., R. 90 W. Breaks occur throughout the vicinity of the study area and are interspersed with flat areas such as that adjacent to Separation Creek. Separation Creek has 5- to 10-foot high banks throughout much of its course.

The Red Rim is the most prominent feature in the study area vicinity. It is a northeast-southwest trending hogback 200-feet high. To the northwest are a series of dissected cuestas becoming flatter as the dip of underlying strata becomes more horizontal. In several areas differential erosion has left unusual, strange shaped rock formations as shown by photographs on pages 15 and 16. These areas are primarily adjacent to the Red Rim but some of the formations are also located in the area immediately southeast of Separation Creek.

The "Eagles" rock formation near deep drill Hole No. 7 which looks like a pair of large birds.

Photo 1

The "Stone Hut," odd rock formation near deep drill Holes No. 3 and No. 4. Pile of rocks on top is a "Sheepherder's Monument."

Photo 2

View of the "Turtle," an unusual shaped sandstone formation on the project area.

Photo 3

The "Snail," strangely shaped sandstone formation in the project area.

Photo 4

The primary formation within the Riner Quadrangle is the Tertiary Fort Union Formation. In the southeast corner of the quad, the underlying Cretaceous Lance Formation is exposed. In the northwest corner of the quad, the Eocene Wasatch crops out as the overlying bed of the Fort Union.

Drilling and surface information as shown on Saunders map (1974) indicates that the Paleocene Fort Union Formation is approximately 1,500-feet thick locally. Below this formation is a 500- to 600-foot thick sandstone which lies uncomfortably upon the Cretaceous Lance Formation. The Lance Formation, which is 3,800-feet thick, is underlain by the Lewis shale and the Mesaverde Formation, also Cretaceous in age. The Lewis shale is approximately 2,000-feet thick and the Mesaverde Formation was not drilled through.

The major constituent materials underlying the Fort Union are: Lance Formation, sandstone and shale, Lewis shale, shale, Mesaverde Formation, sandstone, shale, and coal (Sanders, 1974).

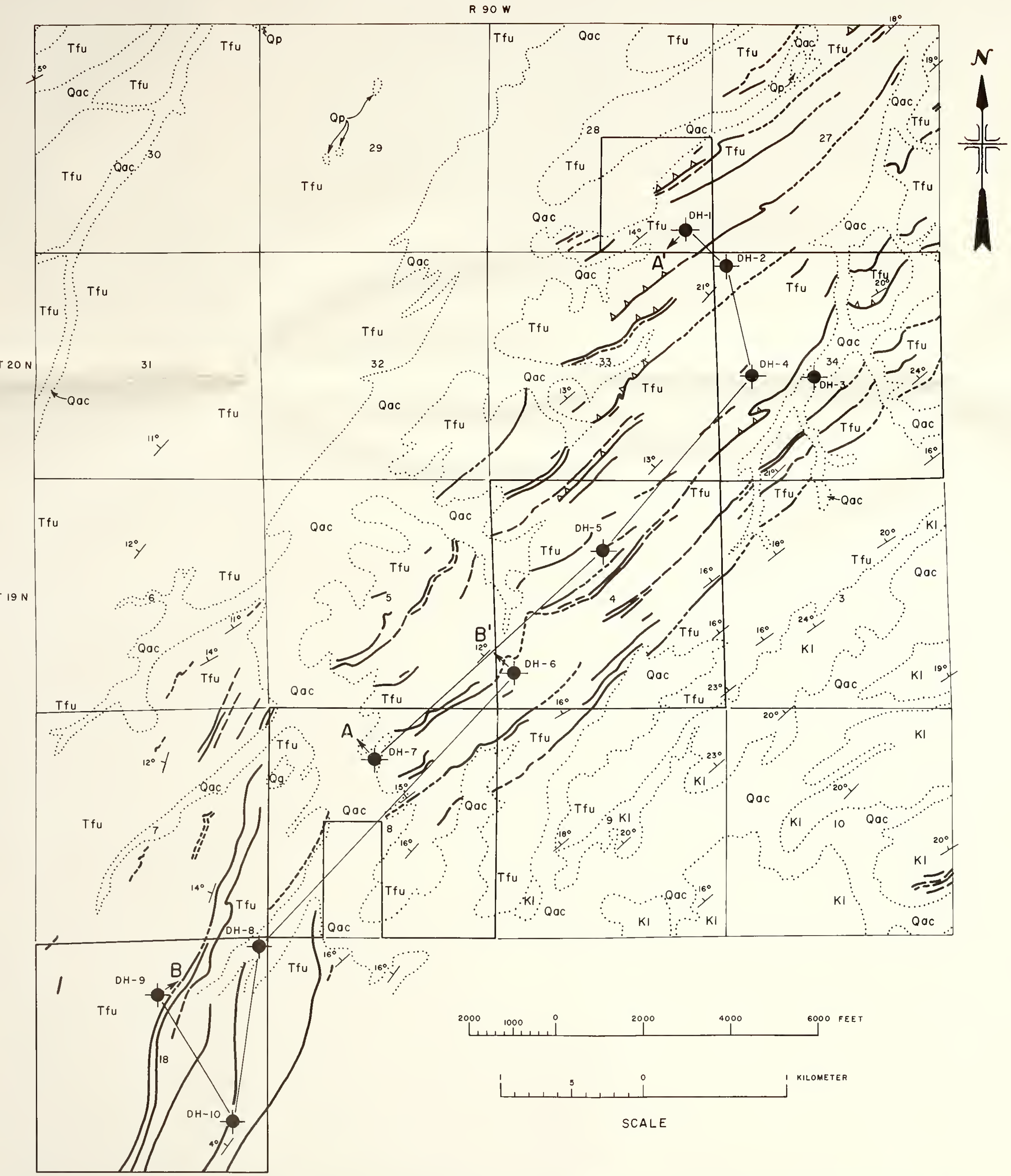
The middle to lower Fort Union Formation, prime coal-bearing formation in the Riner Quadrange. is about 2,000-feet thick including the basal sandstone member. The Fort Union Formation is composed primarily of siltstone, sandstone, shale, and coal. More detailed descriptions of the Fort Union in the study area are found in the drill logs and geologic maps.

Geologic Logs, Map, and Cross Section

The geologic logs of drill holes DH-1 through DH-10 are shown in appendix A. These logs have been revised to include a comparison of the various rock types encountered in the drill holes with the suitability of using these rock types as a plant growing medium. Ratings of suitable, doubtful, and unsuitable are used and the basis for these ratings are discussed under "Overburden Evaluations."

The approximate location of the above drill holes is shown on the surface geologic map, plate 1. This map also indicates the locations of the geologic cross sections. Photographs showing the drill sites and surrounding Red Rim area are shown on pages 19 through 23.

Geologic cross sections shown on plate 2, drawing number X-700-123, are included to demonstrate general stratigraphic correlation. The dip of beds shown is adjusted for vertical exaggeration and is shown as an apparent dip along line of section. Specific correlation of coal beds is described in the coal resources narrative.



EXPLANATION

Qac — ALLUVIUM AND COLLUVIUM UNDIVIDED — Mainly unconsolidated poorly sorted argillaceous silt but locally reflects lithologies of adjacent units.

Qp — PLAYA LAKE DEPOSITS — Light-gray-brown compact expandable clay, the surface of which is seasonally "whitened" by alkali salts. Quartz or ganister ventifacts 1-2 inches in diameter litter surface of playa but not adjacent colluvial areas.

Qg — GRAVEL — Unconsolidated, poorly sorted; composed of subrounded quartzite, granite, and dark chert pebbles similar to those of Qpg from which they are probably derived. In part as terrace remnants 55-85 feet above Separation Creek.

Tfu — SILTSTONE, SANDSTONE, SHALE, AND COAL — Complexly interbedded commonly lenticular or discontinuous sequence of beds. Sandstone, light-colored, argillaceous, fine-to medium-grained; commonly contains ferruginous concretions. Siltstone, light-brown to orange, commonly ferruginous, argillaceous. Shale, light-to dark-gray, locally maroon; locally contains numerous plant fossils. Coal beds are generally thin and discontinuous with lenticular thickenings to as much as 9 feet. Plant, Uniolid pelecypod, viviparid gastropod, turtle, and crocodilian fossils locally numerous. Approximately 1500 feet thick.
SANDSTONE — Light-gray (weathers pink, red, or brown), thick-bedded to massive, medium- or coarse-grained, generally crossbedded; contains well-rounded 0.5-inch chert pebbles. Chert pebbles are common in stringers in basal units. Dark-gray shales separate the generally disconformable sandstones locally. Approximately 500-600 feet thick.

Kl — SANDSTONE AND SHALE — Interbedded light-gray sandstone and medium-to dark-gray and gray-green shale. Plant fragments are locally numerous in the shale. Upper 100 feet contains pebble-bearing white sandstone lithologically similar to the basal beds of the Fort Union Formation from which it can be distinguished by its less massive nature, by the presence of large bone fragments (rare), and by an overlying unit of 20 feet of greenish-gray shale. Approximately 3800 feet thick.

SYMBOLS

Coal bed outcrop — dashed where approximately located, short dashes indicate inferred or indefinite location.

Burned coal bed — approximately located.

Formational contact.

16° Strike and dip of strata.

DH-6 Location of drill hole.

A A' Location of geologic cross section.

Note: Geology based on U.S.G.S. Coal Investigations Map C-68, Geologic Map and Coal Resources of the Riner Quadrangle, Carbon and Sweetwater Counties, Wyoming by Robert B. Sanders, 1974.

For geologic cross sections A-A' and B-B' see Drawing Number X-700-123.

For detailed subsurface data see individual drill logs and Drawing Number X-700-123.

Geology for Section 18, T 19 N, R 90 W from Coal section of this report, by J. Hatch, U.S.G.S.

PLATE I

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES

RED RIM SITE, WYOMING

SURFACE GEOLOGIC MAP

GEOLOGY J. M. Walker	SUBMITTED John M. Walker
DRAWN E. H. F.	RECOMMENDED N. B. Bennett III
CHECKED gmw	APPROVED R. C. Pifer
DENVER, COLORADO FEBRUARY 6, 1976	X-700-122

Site of Deep Hole No. 1

Photo 5

Site of Deep Hole No. 2

Photo 6

Site of Deep Hole No. 3

Photo 7

Site of Deep Hole No. 5

Photo 8

Site of Drill Hole No. 7 looking west.

Photo 9

Site of Drill Hole No. 8 viewing south.

Photo 10

Site of Drill Hole No. 10 viewing southwest showing core boxes prior to transfer to the Denver Regional Soils and Water Laboratory.

Photo 11

Viewing south from southeastern edge of section 7 towards Deep Hole No. 8 which is located near trailer in the center of photograph in northeastern corner of section 18.

Photo 12

Viewing east from southeastern edge of section 7 towards the Red Rim formation in the background.

Photo 13

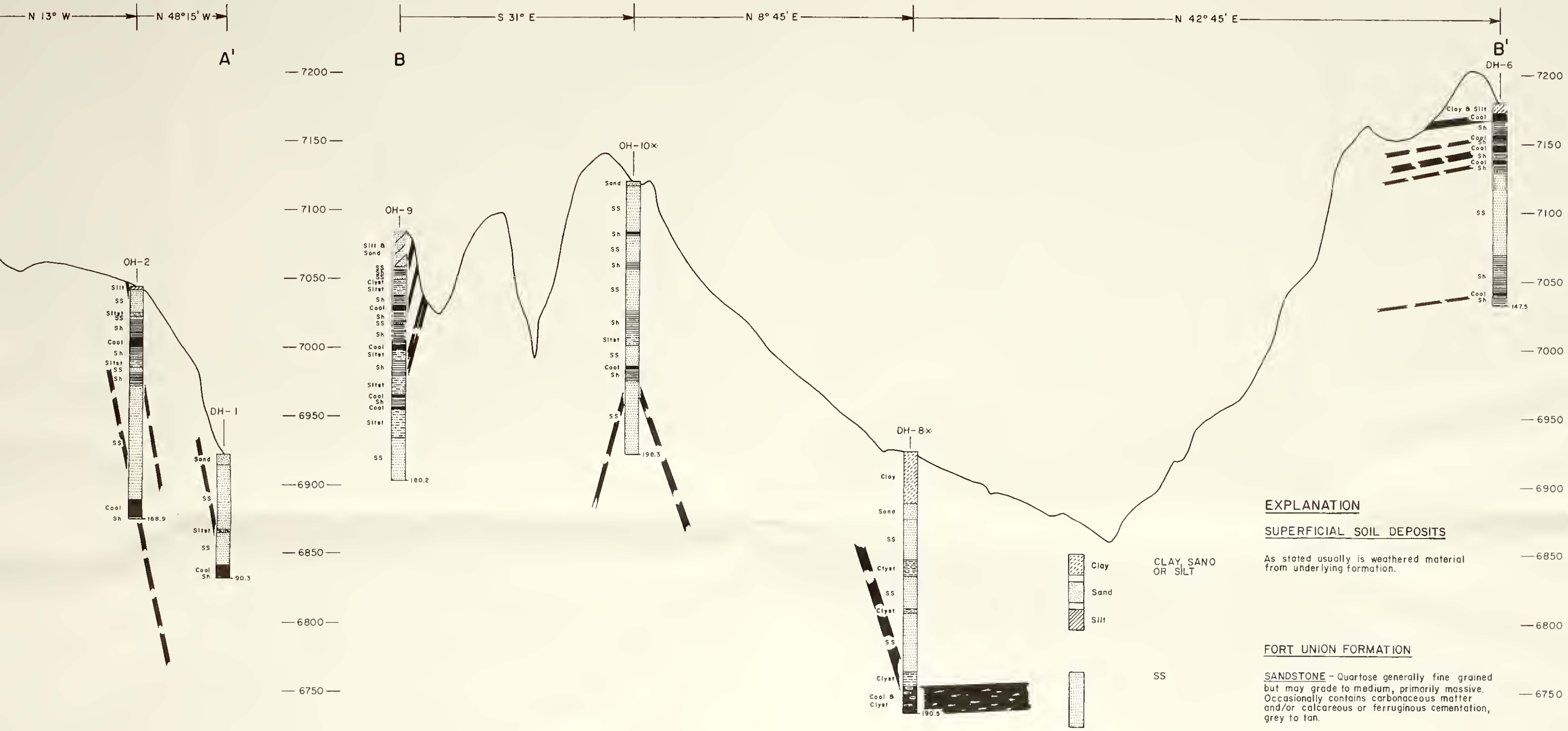
NOTE

Oip of cool beds adjusted for vertic
exageration and shown as apparent di
along line of section.

See Orawing Number X - 700 - 122
for location of sections.

× Oenotes major direction change in
Cross Section.

Note: Dips of the cool seams shown in the sections have been corrected for apparent dip and vertical exaggeration. For locations of section see Drawing Number

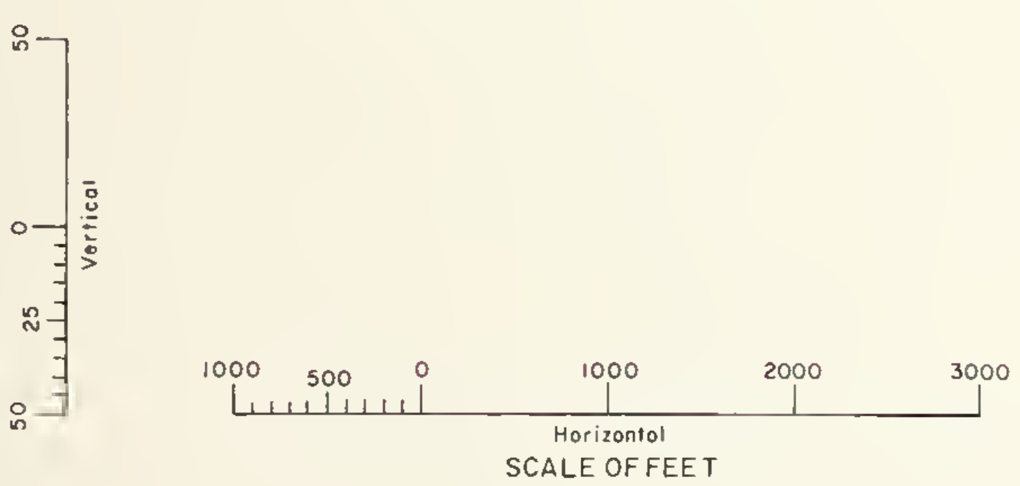


NOTE

Dip of coal beds adjusted for vertical exageration and shown as apparent dip along line of section.

See Drawing Number X - 700 - 122 for location of sections.

× Denotes major direction change in Cross Section.



Note: Dips of the coal seams shown in the sections have been corrected for apparent dip and vertical exaggeration. For locations of section see Drawing Number

EXPLANATION

SUPERFICIAL SOIL DEPOSITS

Clay / Sand / Silt	CLAY, SAND OR SILT	As stated usually is weathered material from underlying formation.

FORT UNION FORMATION

SS	SANDSTONE	Quartose generally fine grained but may grade to medium, primarily massive. Occasionally contains carbonaceous matter and/or calcareous or ferruginous cementation, grey to tan.
SH	SHALE	Silty, carbonaceous, compact, cracks upon drying and breaks down upon wetting. Locally contains very thin coal seams, grey to dark grey.
CLYST	CLAYSTONE	Similar to shale but softer, cracks upon drying and breaks down upon rewetting, grey to dark - grey.
SLTST	SILTSTONE	Clayey and/or sandy and/or carbonaceous, occassionally calcareous, grey to dark grey.
COAL		Sub - bituminous

PLATE 2

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES

RED RIM SITE, WYOMING
GEOLOGIC CROSS SECTIONS

GEOLOGY J. M. Walker	SUBMITTED John M. Walker
DRAWN E.H.F.	RECOMMENDED T. B. Bennett III
CHECKED JMW	APPROVED R. A. Piper
DENVER, COLORADO FEBRUARY 12, 1976	X - 700 - 123

COAL

Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristics of the varieties of coal" (Schopf, 1956). Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern-day peat deposits are formed. The peat then underwent a long, extremely complex process called "coalification" during which diverse physical and chemical changes occurred as the peat changed to coal and the coal assumed the characteristics by which we differentiate Members of the series from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

1) The mode of accumulation and burial of the plant debris forming the deposits.
2) The age of the deposits and their geographical distribution.
3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.
4) The chemical composition of the coal-forming debris and its resistance to decay.
5) The nature and intensity of the plant-decaying agencies.

6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussions of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113; Francis, 1961, p. 361), but the classification by rank--that is, by degree of metamorphism in the progressive series which begins with peat and ends with graphocite (Schopf, 1966)--is the most commonly used system. Classification by types of plant materials is commonly used as a descriptive adjunct to rank classification when sufficient mega and microscopic information is available, and classification by type and quantity of impurities (grade) is also frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources--such factors as the weight of the coal, the thickness and areal extent of the individual coal beds, and the thickness of overburden are generally considered.

Rank of coal

The position of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperatures and pressure to which the coal has been subjected and the duration of time of subjection. Because it is by definition largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constituents--the higher rank coals have more carbon and less hydrogen and oxygen than the lower ranks.

Two standardized forms of coal analyses--the proximate analysis and the ultimate analysis--are generally used in the world today, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bur. Mines, 1956, p. 121-122):

> "The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cakelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference."

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound: one Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree fahrenheit (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure 4 compares in histogram form the heating value and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used but the most commonly employed are the "Standard specifications for classification of coals by rank," adopted by the American Society for Testing and Materials (1974, table 2).

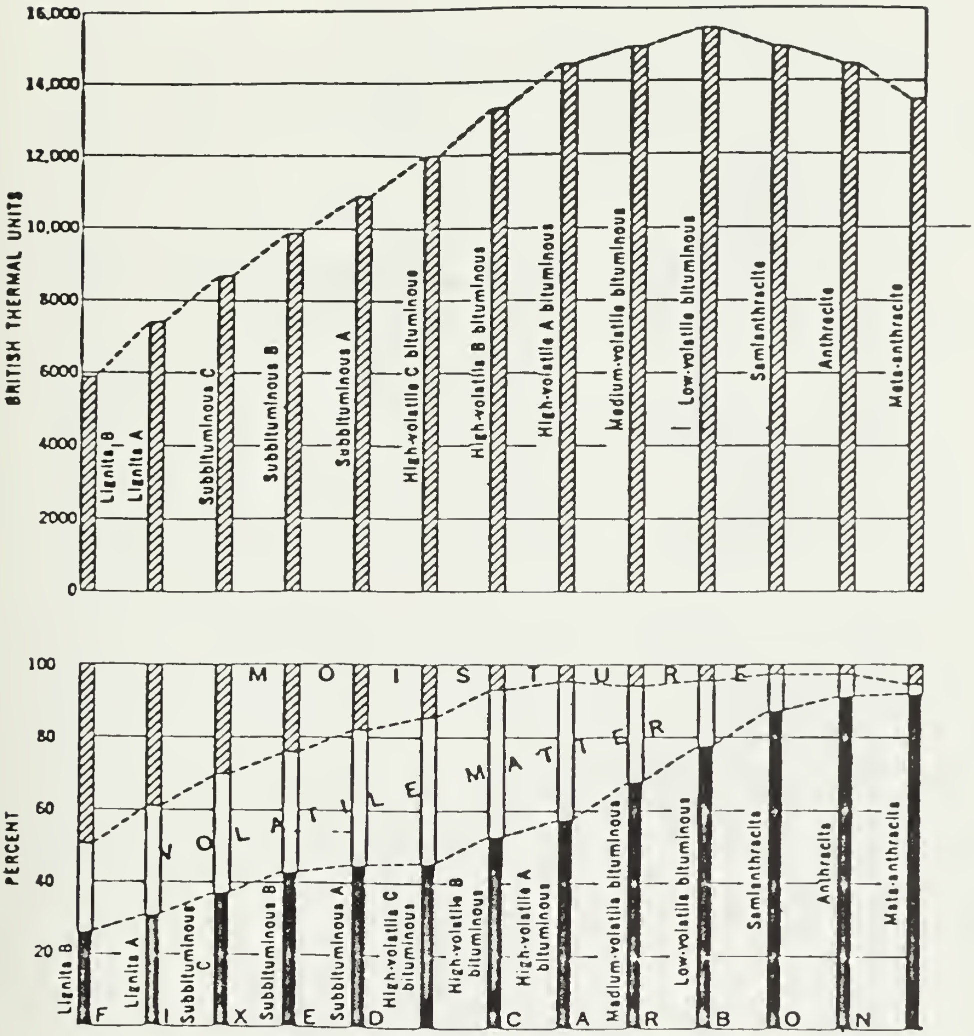


Figure 4 . --Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks.

Table 2 Classification of coals by rank[1]
[American Society for Testing and Materials Standard D388-66 (Reapproved 1972)]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent (Dry, Mineral, Matter-Free Basis)		Calorific Value Limits, Btu per pound (Moist,[2] Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracite	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	nonagglomerating
	3. Semianthracite[3]	86	92	8	14	...	...	nonagglomerating
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	Commonly agglomerating[5]
	3. High volatile A bituminous coal	...	69	31	...	14 000[4]	...	Commonly agglomerating[5]
	4. High volatile B bituminous coal	...	...	...	...	13 000[4]	14 000	Commonly agglomerating[5]
	5. High volatile C bituminous coal	...	...	...	...	11 500	13 000	Commonly agglomerating[5]
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	...	...	...	...	9 500	10 500	nonagglomerating
	3. Subbituminous C coal	...	...	...	...	8 300	9 500	nonagglomerating
IV. Lignitic	1. Lignite A	...	...	...	...	6 300	8 300	nonagglomerating
	2. Lignite B					...	6 300	nonagglomerating

[1]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3]If agglomerating, classify in low-volatile group of the bituminous class.

[4]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value supplemented by determination of agglomerating (caking) characteristics. As pointed out by the ASTM (1974, p. 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

COAL RESOURCES

There at at least ten different coal-bearing horizons exposed in the Red Rim study area. These have been given letter designations by Rocky Mountain Energy Company; A being the coal zone highest in the stratigraphic section and H the lowest. Of the ten coal-bearing horizons in the section, four (F_2, F_1, D_1, and B) appear to contain coal of sufficient thickness and continuity to be of interest. The stratigraphic relationships of the coal encountered in the core holes at the Red Rim study area are shown in figure 5.

Rocky Mountain Energy Company has extensively sampled the coal in the odd numbered sections immediately west of the sections included in the study site and have kindly consented to their data being used to summarize coal quality in the area. Averages of the proximate sulfur and Btu analyses, on an as-received basis, for each significant bed and a summary average for all samples from the area are shown in table 3. For comparison, analyses of samples collected from core, Red Rim study area, are summarized in table 4. Samples are described and the data listed in Appendix B, tables B1 and B2.

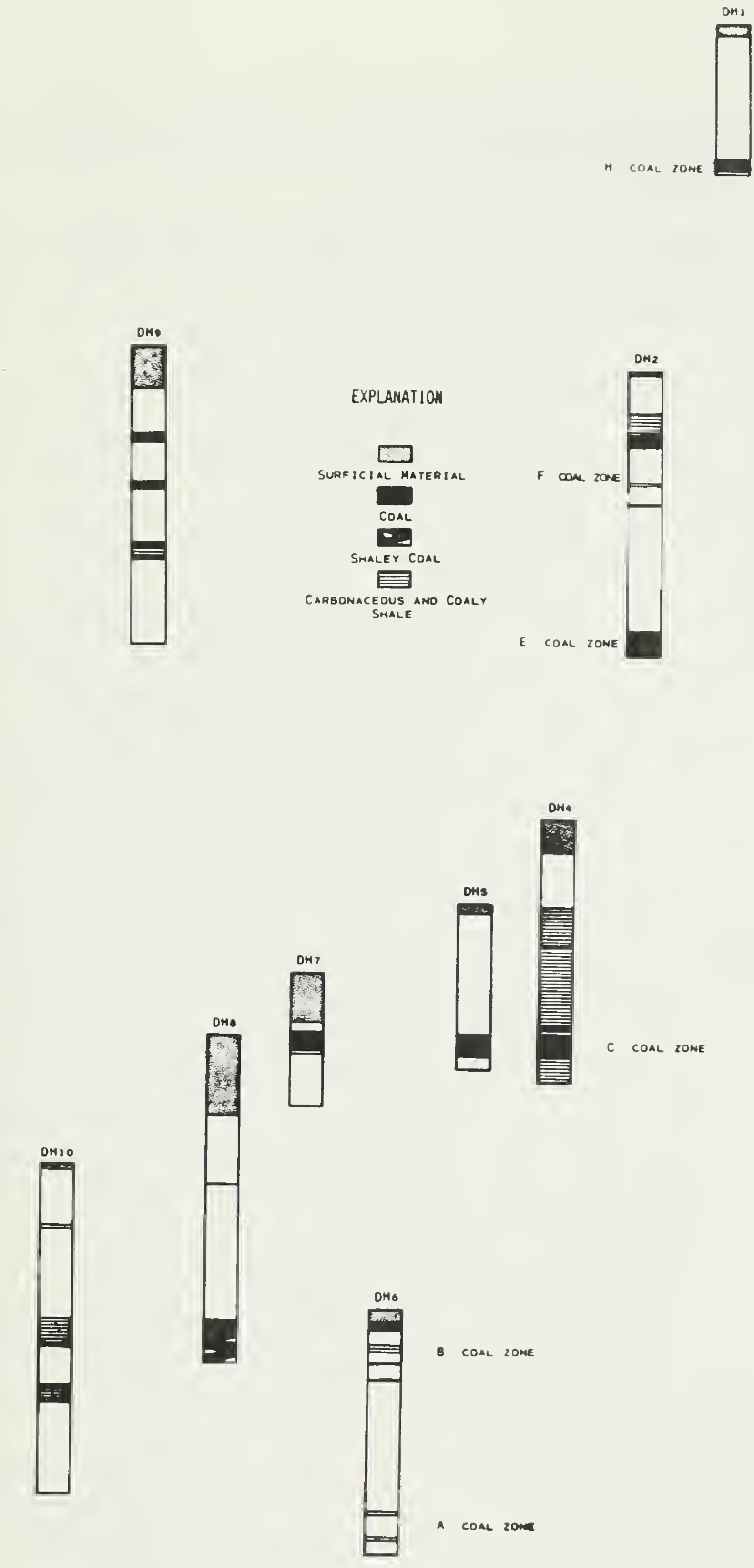


FIGURE 5. STRATIGRAPHIC RELATION OF DRILL HOLES

Table 3.--Summary of proximate, sulfur, and Btu analyses of coal samples collected by Rocky Mountain Energy Company, Red Rim area, Carbon and Sweetwater Counties, Wyo.

[All values except Btu are in percent and are reported on an as-received basis]

Bed number	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
B (2 samples)	23.2	29.0	34.1	13.7	0.39	7910
D_1 (4 samples)	26.0	29.4	38.5	6.0	.43	8550
F_1 (6 samples)	23.8	28.6	33.6	13.9	.57	7840
F_2 (4 samples)	25.1	29.1	36.9	8.9	.27	8230
G (1 sample)	27.3	27.6	38.8	6.3	.25	7850
Average for all beds (17 samples)	24.7	28.9	35.9	10.4	.40	8110

Table 4.--Summary of proximate, sulfur, and Btu analyses of coal samples ollected from core, Red Rim study area, Carbon and Sweetwater Counties, Wyo.

[All values except Btu are in percent and are reported on an as-received basis. Weighted averages of the following sets of samples were used to calculate the averages listed: D178452, D178453, D178454, and D178455; D178456, D178457, D178458, and D178459; D178460, D178401, D178462, and D178463; D178464, and D178465: and D178470, and D178471]

Bed number	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
D_1 (1 sample)	26.1	23.8	32.7	17.4	0.6	7220
E zone (3 samples)	23.0	27.1	34.9	14.8	1.2	7610
F_1 (1 sample)	23.2	26.4	36.7	13.7	.9	7860
F_2 (3 samples)	24.3	28.1	38.1	9.5	.5	8131
G (3 samples)	24.9	22.9	26.5	25.6	1.0	5813
H (1 sample)	29.7	21.6	30.7	18.0	.4	6480
Average for all beds (12 samples)	24.6	25.5	33.2	16.6	.8	7190

Ranges of analyses on an ash-received basis are:

	Rocky Mountain Energy Co.	Red Rim Study Area
Moisture	21.5 - 29.5%	17.8 - 30.0%
Volatile Matter	27.5 - 31.3%	18.1 - 34.0%
Fixed Carbon	31.2 - 39.8%	9.3 - 40.3%
Ash	5.6 - 19.4%	6.1 - 51.6%
Sulfur	0.11- 0.77%	0.3 - 1.7%
Btu	7320 - 8860	2370 - 8750

The above analyses indicate that when calculated to a moist, mineral-matter-free basis, the coal is ranked as Subbituminous C under ASTM Designation D388-66. Ranges of analyses for the Red Rim study are much greater than those obtained by Rocky Mountain Energy Company, probably because Rocky Mountain Energy was more selective in their sampling.

Estimation and classification of coal resources

Coal resource estimates have been prepared for the Red Rim reclamation study area using standard procedures, definitions, and criteria of the U.S. Geological Survey and U.S. Bureau of Mines established for making coal resource appraisals in the United States. The term "coal resources" as used in this report means the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

Resources categorized by degree of geologic assurance

Demonstrated coal resources are the sum of the coal in both measured and indicated resource categories.

Measured resources are coal for which estimates of the rank, quality, and quantity have been computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well-known sample sites.

Indicated resources are coal for which estimates of the rank, quality, and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

Because of the lack of definitive sample analyses of the coal in the EMRIA study site itself, the estimated resources of the Red Rim area are classed as demonstrated or inferred resources. All of the estimated demonstrated resources of the area are within 3/4 mile of points of observation. The inferred resources are within 2 miles of points of observation. The part of the estimated resources that are more than 5 feet thick and are at depth of 100 feet or less fall into a category called reserve base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves are that

portion of the identified coal resource that can be economically mined at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the reserve base. On a National basis, the estimated recovery factor for the total reserve base is 50 percent. More precise recovery factors can be computed by determining the total coal in place and the total coal recoverable in any specific locale.

Characteristics used in resource evaluation

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal, the thickness of the coal beds, and the thickness of the overburden. Rank and grade have been discussed previously.

The weight of coal ranges considerably with differences in rank and ash content. In areas such as the Red Rim area, where specific gravities of the coals have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of subbituminous coak is taken as 1,770 short tons per acre-foot--a specific gravity of 1.30.

Because of the important relation of coal-bed thickness to utilization potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. For subbituminous coal the categories are thin--2.5 to 5 feet (0.75 to 1.5 m); intermediate--5 to 10 feet (1.5 to 3 m); and thick--more than 10 feet (3 m).

In this report, coal resources estimated for the Red Rim area are those resources overlain by 200 feet (60 m) or less of overburden.

Tables 5, 6, and 7 present the estimated demonstrated and inferred coal resources in the F_1, F_2, D_1, and B coal beds in the Red Rim recalmation study area by section, bed thickness category, and overburden thickness category. The estimated resources (demonstrated plus inferred) are summarized by bed and overburden thickness category in table 8.

Table 5.--Demonstrated resources of the Red Rim reclamation study area, Sweetwater County, Wyo.

[in thousands of short tons; one short ton equals 0.9 tonnes]

Township and range	Section	Zone	Overburden thickness in feet: 0 to 100, Coal thickness in feet: 2 1/2-5	5-10	10 and more	Total	100 to 200, Coal thickness in feet: 2 1/2-5	5-10	10 and more	Total	0 to 200, Coal thickness in feet: 2 1/2-5	5-10	10 and more	Total
20 N 90 W	22	D_1	----	----	----	----	----	50	----	50	----	50	----	50
		B	30	----	----	30	100	----	----	100	130	----	----	130
	Total		30	----	----	30	100	50	----	150	130	50	----	180
	27	F_2	----	130	----	130	----	290	----	290	----	420	----	420
		F_1	----	650	270	920	----	1240	920	2160	----	1890	1190	3080
		D_1	----	570	----	570	----	630	----	630	----	1200	----	1200
		B	570	----	----	570	500	----	----	500	1070	----	----	1070
	Total		570	1350	270	2190	500	2160	920	3580	1070	3510	1190	5770
	28 EMRIA	F_1	----	----	----	----	----	----	40	40	----	----	40	40
	EMRIA	D_1	----	160	----	160	----	360	----	360	----	520	----	520
	EMRIA	B	500	----	----	500	130	----	----	130	630	----	----	630
	Whole	B	940	----	----	940	720	----	----	720	1660	----	----	1660
	Total		940	160	----	1100	720	360	40	1120	1660	520	40	2220
	32	D_1	----	280	----	280	----	490	----	490	----	770	----	770
	33	F_2	----	130	60	190	----	----	730	730	----	130	790	920
		F_1	----	2220	40	2260	----	1540	430	1970	----	3760	470	4230
		D_1	510	280	----	790	730	30	----	760	1240	310	----	1550
		B	120	----	----	120	----	----	----	----	120	----	----	120
	Total		630	2630	100	3360	730	1570	1160	3460	1360	4200	1260	6820
	34	F_2	----	450	430	880	----	480	590	1070	----	930	1020	1950
		F_1	----	----	930	930	----	----	430	430	----	----	1360	1360
	Total		----	450	1360	1810	----	480	1020	1500	----	930	2380	3310
Total			2170	4870	1730	8770	2050	5110	3140	10300	4220	9980	4870	19010

Table 6.--Demonstrated resources of the Red Rim reclamation study area, Carbon County, Wyo.

[in thousands of short tons; one short ton equals 0.9 tonnes]

Township and range		Section	Zone	Overburden thickness in feet: 0 to 100, Coal thickness in feet: 2 1/2-5	0 to 100: 5-10	0 to 100: 10 and more	Total	100 to 200, Coal thickness in feet: 2 1/2-5	100 to 200: 5-10	100 to 200: 10 and more	Total	0 to 200, Coal thickness in feet: 2 1/2-5	0 to 200: 5-10	0 to 200: 10 and more	Total
20 N	90 W	23	F_1	----	----	----	----	----	260	----	260	----	260	----	260
		26	F_2	----	450	----	450	----	600	----	600	----	1050	----	1050
			F_1	----	580	----	580	----	610	----	610	----	1190	----	1190
		Total		----	1030	----	1030	----	1210	----	1210	----	2240	----	2240
Total				----	2060	----	2060	----	2680	----	2680	----	4740	----	4740
19 N	90 W	4	F_2	----	----	2070	2070	----	----	1470	1470	----	----	3540	3540
			F_1	----	40	----	40	----	160	----	160	----	200	----	200
		Total		----	40	2070	2110	----	160	1470	1630	----	200	3540	3740
		5	F_2	----	----	510	510	----	470	50	520	---	470	560	1030
			F_1	----	1080	----	1080	----	1680	----	1680	----	2760	----	2760
		Total		----	1080	510	1590	----	2150	50	2200	----	3230	560	3790
		7	F_2	----	----	190	190	----	----	510	510	----	----	700	700
			F_1	----	----	----	----	----	110	----	110	----	110	----	110
		Total		----	----	190	190	----	110	510	620	----	110	700	810
		8	F_2	----	----	1910	1910	----	----	1440	1440	----	----	3350	3350
			F_1	----	350	----	350	----	230	----	230	----	580	----	580
		Total		----	350	1910	2260	----	230	1440	1670	----	580	3350	3930
		18	F_2	----	----	1540	1540	----	----	1550	1550	----	----	3090	3090
			F_1	270	----	----	270	300	----	----	300	570	----	----	570
		Total		270	----	1540	1810	300	----	1550	1850	570	----	3090	3660
Total				270	1470	6220	7960	300	2650	5020	7970	570	4120	11240	15930

Table 7.--Inferred resources of the Red Rim reclamation study area, Sweetwater County and Carbon County, Wyo.

[in thousands of short tons; one short ton equals 0.9 tonnes]

Township and range		Section	Zone	Overburden thickness in feet: 0 to 100, Coal thickness in feet: 2 1/2-5	0 to 100: 5-10	0 to 100: 10 and more	Total	100 to 200, Coal thickness in feet: 2 1/2-5	100 to 200: 5-10	100 to 200: 10 and more	Total	0 to 200, Coal thickness in feet: 2 1/2-5	0 to 200: 5-10	0 to 200: 10 and more	Total
							Sweetwater County								
20 N	90 W	22	B	490	----	----	490	610	----	----	610	1100	----	----	1100
							Carbon County								
20 N	90 W	23	F_1	----	----	----	----	----	520	----	520	----	520	----	520
		26	F_1	----	20	----	20	----	60	----	60	----	80	----	80
Total				----	20	----	20	----	580	----	580	----	600	----	600
19 N	90 W	7	F_1	120	----	----	120	260	----	----	260	380	----	----	380
		8	F_1	----	100	----	100	----	----	----	----	----	100	----	100
		18	F_1	20	----	----	20	20	----	----	20	40	----	----	40
Total				140	100	----	240	280	----	----	280	420	100	----	520
Grand total Carbon County				140	120		260	280	580		860	420	700		1120

Table 8.--Summary of estimated coal resources of the Red Rim reclamation study area, by bed and overburden thickness

[In thousands of short tons]

Overburden thickness (ft)	Bed F_2	Bed F_1	Bed D_1	Bed B	Total
0-100	7,870	6,690	1,800	2,150	18,510
100-200	8,180	8,810	2,290	1,930	21,210
0-200	16,050	15,500	4,090	4,080	39,720

INTERPRETATIONS FOR SOIL AND BEDROCK MATERIAL AS A POTENTIAL SOURCE FOR REVEGETATION

Major Soil Bodies

Four major geomorphic bodies of soils, in terms of landform are recognized in the Red Rim study area. They are soils on (1) alluvial soils on nearly level to gently sloping floodplains and adjacent alluvial fans, (2) gently sloping to strongly sloping upland hillsides, the landscape is made up of rolling uplands that are dissected by numerous drainageways, (3) moderately sloping to steep hillsides and smooth, moderately sloping ridges with isolated areas of sandstone outcrop, and (4) moderately sloping to very steep, severely eroded ridges and hillsides. The primary difference between (3) and (4) is that (3) is primarily a complex landscape of very shallow to deep, very coarse textured soils which are basically noncalcareous, and (4) is a complex landscape of shallow soils and exposed sandstone, siltstone, and sandy shale bedrock.

The following is a description of the soils which occur on the four landforms in the Red Rim study site: (Note: Reference is made at random to the soils on each landform by the number in parentheses).

(1) The alluvial floodplain and fan soils are primarily along Separation Creek and represent, 10 percent of the study area, a minor portion of the total acreage of the site. These soils are formed on alluvium of mixed origin. They are deep, well-drained, light colored soils of medium texture. Their available water holding capacity is medium and permeability is moderate to moderately slow.

Depth to consolidated material is assumed to be greater than 20 feet because of the thick alluvial deposits. Depth to unconsolidated material on the upper edges of alluvial fans is about 5 feet and deepens considerably towards the creek. Electrical conductivity of the saturation extract ranges from 4 to 8 mmhos/cm^3 and exchangeable sodium is generally less than 10 percent. The pH values range from 7.6 - 8.5. There are, however, two small areas in section 8 adjacent to the creek which are adversely affected by both salinity and sodium. Generally, soils of this landform have a fair suitability for revegetation purposes.

(2) Soils which occur on this landform include moderately deep and deep soils formed in residuum from the weathering of calcareous sedimentary rocks. They occupy about 40 percent of the study area. The parent rock of these soils is variable, the major types being soft unconsolidated sandstone and sandy shale.

These soils are well-drained and their colors include browns, grayish browns, and yellowish browns. Normally, the upper 10 to 20 inches of soil material has developed structurally and the lower depths are completely lacking in aggregation of soil particles.

The soil permeability is moderate with the exception of a small acreage which is slow. Available water capacity ranges from moderate to high. Sandy loam topsoils (the A horizon) sandy clay loam subsoils, and sandy loam substratums are dominant. However, subsoils of sandy loam, clay loam, and loam are included. Depth to carbonates in those soils which exhibit solum development range from 8 to more than 20 inches. These compromise about 65 percent of this particular land form. The remaining 35 percent are calcareous to the surface. As a general rule, the degree of alkalinity is mild or moderate (pH from 7.4 - 8.5). Generally, the exchangeable sodium percentage is insignificant with a slight increase with depth. Salinity levels are fairly low. For the most part, the soils of this landform are well suited for use as a planting media.

(3) This landform includes very shallow soils (20 inch to sandstone) which are forming in residuum weathered from noncalcareous hard sandstone and deep (more than 60 inches to sandstone) wind deposited soils that occur on stabilized dunes. 30 percent of the study area consists of this soil group. Characteristics which are common to both soils are fine sand or loamy sand textures that have low water holding capacities and very rapid infiltration rates. Structure is single grained, organic matter content is low and brown colors (pale brown, yellowish brown, and light yellowish brown) are common.

These soils are generally neutral with pH ranging from 6.8 to 7.4. The shallow soils are generally noncalcareous throughout the profile. The deeper soils are noncalcareous in the upper 30 to 40 inches and slightly calcareous below those depths. These soils generally are poorly suited for strip mine reclamation purposes.

(4) Soils occurring on this landform, which covers 20 percent of the study area, are formed in residuum weathered from calcareous sedimentary rock, primarily soft unconsolidated sandstone, hard fine-grained sandstone, and sandy shales. The depth to bedrock normally ranges from 14 to 20 inches. They are well-drained and the water holding capacity for the profile is moderately low. The in-place permeability is moderately slow. Moderate grades of structure predominate in the upper 4 inches of these soils and the subsoil and substratum are normally structureless. Color of the surface layer is brown or pale brown, the subsoil is pale brown, light yellowish brown, or brown and the substratum is yellowish brown or pale brown. About 80 percent of this area is represented by soils which are calcareous throughout, while the remainder is normally leached of carbonates to a depth of 6 to 10 inches and these soils occur on smooth remnant slopes.

Generally, soils occurring on this landform are poorly suited for strip mine reclamation purposes. The steep slopes and rock outcrops of these lands are unsuitable as a source of material for surfacing the shaped spoils.

Overburden Characteristics

Land Suitability

A detailed land suitability survey was made of the study area land. Its purpose was to characterize and evaluate the surface and upper material (5 feet) in relation to its suitability as a source of planting media for resurfacing shaped spoils following surface mining. This survey provides data on the quality and quantity of surface material in relation to revegetation and the core of stripping. Basis data on the present physical and chemical properties of the soils (upper 5 feet) are also provided by the survey.

Land classification specifications to establish ranges of land suitability as a source of planting media were developed specifically for the study. Factors included in the specifications for quality consideration were: texture, salinity, sodicity, permeability, available water holding capacity, and erodability. Quantity considerations were primarily the depth of suitable material. Excessive slope and bedrock outcrops were factors considered in relation to stripping and stockpiling of material. The specifications for the Red Rim study are given in Table 9 page 50.

Four land classes (1, 2, 3, and 6) were developed. These correspond to classes used in the Bureau of Reclamation land classification system. Class 1 lands are the most desirable as a source of topsoil for surfacing shaped spoils. They will supply a large quantity of highly suitable material which is easily stripped and stockpiled for postmining use on the lands they occupy and possible for adjacent areas where sufficient material is not adequate. Class 2 lands have adequate resurfacing material, but it may require good placement practices to meet the requirements and be less desirable in quality or difficult to strip and stockpile. Class 3 lands are similar to Class 2 except the deficiencies are greater, or there is a combination of deficiencies. Lands in this class are marginal as a source of material, but with good procedures for stripping and stockpiling will meet the requirements. Class 6 lands generally do not have adequate or suitable material for topsoil use or if available, cannot be stripped and stockpiled. If Class 6 lands are disturbed by surface mining, it will be necessary to borrow or improve the available material if revegetation is successful. A summation map showing location and percent of classification in area is shown on page 53.

Field mapping was done on aerial photographs with a scale of 1 inch equals 1,000 feet. Representative soil sites were selected and the profiles examined and evaluated. This information was supplemented by nonrecorded profile examinations as required. The soil profiles were exposed or drilled out with a hand auger. Soil structure, consistence, texture, color, root distribution and other features of the profile were observed on the representative sites recorded. Salinity and sodicity were based primarily on laboratory data. Soil samples for laboratory analyses were collected from representative profiles.

Many of the observable characteristics such as texture, structure, consistency sodicity, etc., were directed at estimating soil-moisture relationships of the material. A tentative land suitability class was established by using these basic soil evaluations combined with observations of other land features such as stones, exposed indurated bedrock, and slope. The final land class was not determined until the laboratory data was available.

Results of the land classification show that approximately two-thirds of the study area has adequate material for postmining reclamation purpose. Deficiencies observed by the survey were shallow depths of weathered material over consolidated or unconsolidated shale and sandstone, salinity, coarse textures, steep slopes, and bedrock outcrops which hinder stripping. Table 10 shows the acreages of the land subclasses delineated by the survey and page 53 shows the location and distribution of land classes. Individual land classification sheets are shown as figures C1 through C5 in appendix C.

The land classification survey provides adequate data for developing lease stipulations and the reclamation portion of the required mining plan. It does not, however, provide adequate detail for stripping and stockpiling operations immediately prior to the surface mining. Procedures similar to those used in the land classification can be used when additional field barings and observations supported by laboratory data are obtained to more accurately determine the quantity, location, and quality of the available material. Following is a description of the major land classes in the land suitability survey.

Class 1 - Lands in this class have an average minimum depth of 36 inches of good quality overburden that is suitable for plant media. These soils have formed generally on residual or colluvial material. The most common textures are fine sandy loam, sandy clay loam, and clay loam. Aggregate stability is weak to moderately strong and water enters the profiles readily. Internal drainage is moderate and adequate moisture is stored for plant use.

These soils are nonsaline and nonsodic. Generally these soils are noncalcareous or slightly calcareous in the upper 12 inches of the soil profile. Some moderately calcareous layers occur below 12 inches.

Land Features - The topography includes gently and moderately sloping upland fans, toe slopes and valley wash of local origin. These topographic features will not hinder stripping and stockpiling of overburden materials.

Class 2s - Land in this class includes: (1) soils which have about 18 inches of good quality material underlain by unconsolidated sandstones and sandy shales which, by present indications, would weather quite readily, (2) soils which have more than 60 inches of

fairly suitable plant media material which are moderately affected by salinity (electrical conductivity of the saturation extract ranges from 4 to 8 mmhos/cm^3). Class 2s lands have textures which are moderately coarse or medium textured.

Stability of soil aggregates is fair, and water movement in the soil is moderate, but adequate to ensure aeration of the primary plant root zone. Adequate moisture can be retained for plant use.

Land Features - Two primary physiographic land forms contain Class 2s lands. These are (1) the alluvial-colluvial fans adjacent to Separation Creek, and (2) lower toe slopes, moderately steep.

Class 3s - Included in this class are lands which are generally shallow to bedrock. They have from 6 to 18 inches of sandy loam, loam, sandy clay loam, or clay loam material which overlie mixed sandy shales and sandstones. Particle aggregation is poorly defined and in many cases, completely lacking. The water holding capacity is low due to coarse texture and shallow profile, but water enters the profiles readily. Internal drainage is moderate to somewhat slow.

These soils are generally nonsodic and nonsaline. However, while not extensive, the electrical conductivity of the saturation extract may range up to 12 millimhos per cubic centimeter. Generally soils in this class are moderately calcareous.

Land Features - The principle physiographic landforms in Class 3s are the rolling, shallow uplands which lie between the more significant drainages and the high ridgecrests and accompanying short side slopes.

Class 6s - An insignificant acreage falls into this land class. They are located along the south edge of Section 8 adjacent to Separation Creek. Soils on these lands are not suited in their present condition for use as a plant growth medium because of a high degree of sodicity and salinity. Generally, the Class 6s lands have an ESP exceeding 20 and $ECx10^3$ of 1:5 extract of more than 12 mm/cc. The soil texture is moderately coarse, with sandy loams being dominant. Because of the dispersed condition of the soil aggregates, very little water is able to enter the profile.

Land Features - The landform on which these soils occur are nearly level alluvial fans where they adjoin Separation Creek.

Class 6st - Within this land class, are those lands which are: (1) so shallow (less than 6 inches of soil material) that stripping operations would be impractical (2) coarse textured which severely limits the moisture holding capacity and which present an erosion (wind) hazard if disturbed, and (3) both shallow (6-18 inches of strippable soil material) and occur on steeply sloping landforms (more than 25 percent slope). Because of the shallow soil depths and steep slopes, these lands are not suited for use as a source of plant growth medium.

Land Features - Generally, the 6st lands occupy the uppermost ridges and very rolling hills within the studysite. Interbedded shales and sandstones may be seen on many of the steep escarpments where vegetation is almost completely lacking. However, a major portion of this land class can be characterized as being formed by aeolian sands which form the rolling hills dissected by drainages. Ledges and knobs of sandstone are part of the setting. The plant community is spiny hopsage, rabbitbrush, Indian ricegrass, needle and thread, and thick spike wheatgrass.

Table 10 gives the acres and percentages of the land classes for the Red Rim study area.

TABLE 9

LAND CLASSIFICATION SPECIFICATION - EMRIA PROGRAM 1/
SUITABILITY OF LAND AS SOURCE OF PLANTING MEDIA FOR SURFACE - MINED RECLAMATION
RED RIM STUDY AREA - LAND CLASS

SOILS 2/	1	2	3
TEXTURE	FSL - CL	SL - C (-)	LFS - SIC
AVAILABLE WATER HOLDING CAPACITY	More than 2.0"/ft.	More than 1.25"/ft.	More than 75"/ft.
PERMEABILITY	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	May be slightly restricted resulting in decreased drainage and aeration in the root zone and at reduced infiltration rate.	Restricted to the extent that internal drainage may limit choice of vegetation and/or require special practices to control erosion.
SALINITY (AT EQUILIBRIUM)	Less than 4 Millimhos.	Less than 8 Millimhos.	Less than 12 Millimhos.
SODICITY	Less than 10 ESP - May be higher if hydraulic conductivity meets limits for Class 1.	Less than 10 ESP - May be higher if hydraulic conductivity meets limits for Class 2.	Less than 15 ESP - May be higher if hydraulic conductivity meets limits for Class 3.
ERODABILITY	Subject to slight erosion.	Subject to moderate erosion.	Susceptible to severe erosion, but can be controlled with proper management.
WEATHERABILITY 3/	Breaks down rapidly upon exposure to normal weathering in the surface environment.	May require a short to moderate period to break down following exposure.	May require an extended period to break down into optimum particle size distribution, but is usable in a practically achievable state with a reasonable time period.
DEPTH	More than 36" of usable and strippable material.	More than 24" of usable and strippable material.	More than 6" of usable and strippable material. 4/

Table 9 (Continued)

RED RIM STUDY AREA

TOPOGRAPHY	1	2	3
SLOPE 5/	Less than 20 percent.	Less than 20 percent.	Less than 25 percent - Can be greater in areas situated at uphill ends of excavated strips where these materials are customarily used.
SURFACE ROCKS Decomposed or fractured sandstone and/or shale.	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-2.5" 10% 2.5-10" less than 10%	Permissible stone in surface soil or in material to be stockpiled and used as surface soil: 0-2.5" 15% 2.5-10" less than 15%	Permissible stone in surface soil or in material to be stock-piled and used as surface soil: 0-2.5" 25% 2.5-10" less than 15%
BEDROCK OUTCROPS 5/	Will not affect stripping or quantity of suitable material.	Numerous enough to reduce quantity of suitable material slightly and make stripping more expensive.	Numerous enough to reduce quantity of suitable material appreciably and make stripping considerably more expensive.
DRAINAGE	Because of land alterations by surface mining, present drainage conditions (with the exception of active streams and their immediate flood plains) are not a factor in the classification. Permeability requirements are covered under Soils.		
Class 6	All areas not meeting requirements for Classes 1, 2, or 3. These lands are unsuited in their present condition as a source of material for revegetation.		

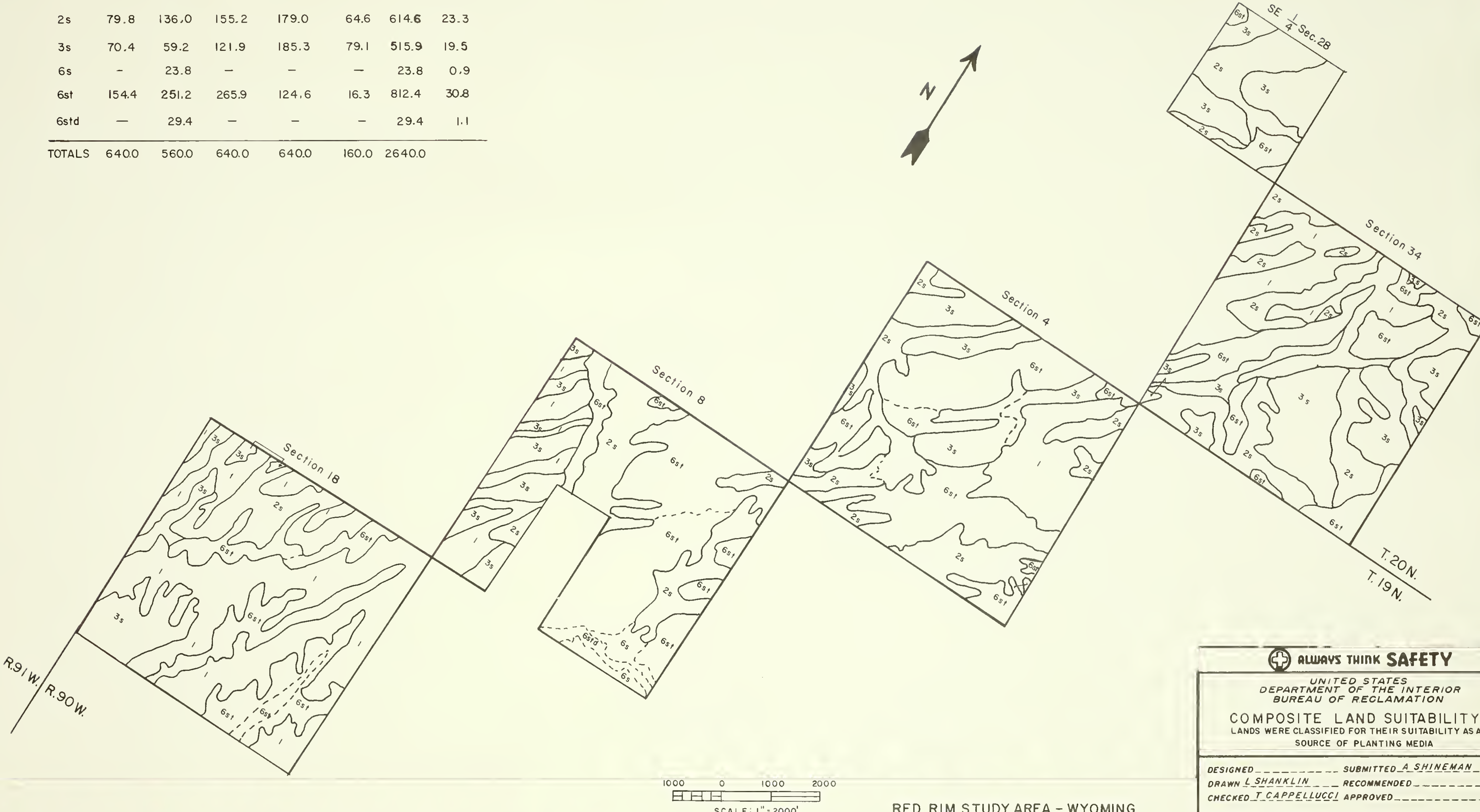
1/ Specifications are based on natural rainfall or minimum irrigation for starting and establishing plantings.
2/ The limitations under Soils are applicable to the evaluation of both the soil and the overburden material between the soil and mineable coal.
3/ Weatherability is applicable only to bedrock or unconsolidated material.
4/ Six inches is considered as the minimum strippable depth.
5/ Related primarily to ease of stripping operations.

Table 10

Land Suitability Summary

Class	Section - Township North - Range West 18-19-90	8-19-90	4-19-90	34-20-90	28-20-90	Total Acres	Percent of Study Area
1	335.4	60.4	97.0	151.1	-	643.9	24.4
2s	79.8	136.0	155.2	179.0	64.6	614.6	23.3
3s	70.4	59.2	121.9	185.3	79.1	515.9	19.5
6s	-	23.8	-	-	-	23.8	0.9
6st	154.4	251.2	265.9	124.6	16.3	812.4	30.8
6std	-	29.4	-	-	-	29.4	1.1
Totals	640.0	560.0	640.0	640.0	160.0	2640.0	100.0

CLASS	SECTION - TOWNSHIP NORTH - RANGE WEST 18-19-90	8-19-90	4-19-90	34-20-90	28-20-90	TOTAL ACRES	PERCENT OF STUDY AREA
1	335.4	60.4	97.0	151.1	—	643.9	24.4
2s	79.8	136.0	155.2	179.0	64.6	614.6	23.3
3s	70.4	59.2	121.9	185.3	79.1	515.9	19.5
6s	-	23.8	—	-	—	23.8	0.9
6st	154.4	251.2	265.9	124.6	16.3	812.4	30.8
6std	—	29.4	—	-	-	29.4	1.1
TOTALS	640.0	560.0	640.0	640.0	160.0	2640.0	



RED RIM STUDY AREA - WYOMING

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COMPOSITE LAND SUITABILITY

LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED	SUBMITTED A. SHINEMAN
DRAWN L. SHANKLIN	RECOMMENDED
CHECKED T. CAPPELLUCCI	APPROVED

LM REGION, DEN., COLO.

Overburden Evaluation
(5 feet to bottom coal seam)

A systematic evaluation was made of the core material, on the basis of the applicable parts of the specifications used for the land classification survey. However, different suitability classes were used on the core evaluations. The suitability class is equivalent to the Class 1 and the better part of Class 2, doubtful to the lower part of Class 2 and Class 3, and unsuitable relates to Class 6. Those materials which qualify for suitable are generally well suited for use as a planting media but may have minor deficiencies. A doubtful designation indicates a usable material but because of identified deficiencies will require good or special management if used for surfacing shaped spoils. The quantity may also be limited.

Unsuited relates to materials which in their present condition would be unproductive if used on the surface. With special management practices such as leaching, use of additives, etc., some of these materials could be altered to a usable condition. The type and quantity of the geologic material is quite diverse and projection of the chemical and physical properties important to its use as a planting media cannot be accurately projected between core locations. Therefore, the quality determination applies only to the specific core site. The ability and case of separating and stockpiling bedrock material, if it should be needed as a planting media, was not a factor in the evaluation. The core material was processed and analyzed in the laboratory and greenhouse using the same procedures as used on soil samples. Simulated weathering was applied to selected samples to provide some indication of how the material would break down when exposed to the weather. The evaluation was based on these studies and the physical appearance of the cores.

The predominant bedrock materials of the area are sandstone and shale. Some of these rock types are quite thickly bedded while others are complexly interbedded. Siltstone and seams of coal and carbonaceous shale occur less frequently. The major deficiencies of the core material in relation to use as a planting media are anticipated fine and coarse-textured weathered material, salinity, dense unweatherable sandstones, and an acid problem on a few depths. Because of the anticipated fine-textured and slowly permeable material resulting from their weathering, the shales generally fall into the doubtful class.

Most of the harmful concentrations of salinity occur in the shales. Coarse-texture material with a low CEC and available water holding capacity and highly permeable could result from the weathered sandstone. Also, many of the more dense sandstones may not weather within a reasonable time into suitable material for a planting media. Generally the core material is nonsodic and nonsaline except for a limited number of lenses which have EC X 10_3 per centimeter ranging between 4 and 6. The material appeared to be relatively low swelling. Except for a 30-foot seam which is acid, the bedrock is neutral to alkaline in reaction.

Results of the core evaluations are presented below and these same evaluations are outlined earlier in this report in the geologic log presentation. Two-inch push samples or hand augered samples were taken in those drill holes where superficial soil deposits or unconsolidated material occurred from 0-10.0 feet.

Depth (feet)	Material	Evaluation	Remarks
	Deep Hole No. RR-1		
0-7.7	Soil	Suitable	
7.7-10.5	Soil	-	0% Core Recovery
10.5-47.0	Sandstone	Doubtful	Coarse Textured 1/
47.0-81.0	Sandstone and Siltstone	Suitable	
81.0-87.8	Coal	Unsuitable	
87.8-90.3	Shale	Suitable	
	Deep Hole No. RR-2		
0-2.7	Soil	Suitable	
2.7-5.0	Sandstone	Doubtful	Salinity (Lab #29)
5.0-18.9	Sandstone	No Recovery	
18.9-22.0	Siltstone	Doubtful	Salinity
22.0-24.0	Sandstone	Doubtful	Coarse Texture 1/
24.0-37.0	Shale	Doubtful	Salinity
37.0-44.0	Coal	Unsuitable	
44.0-66.0	Shale, Siltstone, and Sandstone	Suitable	
66.0-67.0	Coal	Unsuitable	
67.0-72.0	Shale	Doubtful	Salinity, Fine Textured 2/
72.0-154.5	Sandstone	Doubtful	Coarse Textured 2/ Salinity
154.5-168.0	Coal	Unsuitable	
168.0-168.9	Shale	Doubtful	Salinity

Most of the material from 72.0-154.5 feet is a fine-grained sandstone with a hardness of 3-7, and sample RR-2-16, which was representative of this material, exhibited no breakdown at all during the laboratory weathering test. These and similar rock types would be evaluated as doubtful for suitability as a plant growing media.

Deep Hole No. RR-3

No core samples were recovered from Deep Hole No. RR-3 which was used as a ground-water observation hole.

1/ Coarse textured indicated low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

Depth (feet)	Material	Evaluation	Remarks
	Deep Hole No. RR-4		
0-2.5	Soil	Suitable	
2.5-19.0	Sand	Doubtful	Coarse Textured 1/
19.0-23.0	Sandstone	Doubtful	Coarse Textured 1/
23.0-29.0	Sandstone	Suitable	
29.0-39.0	Sandstone	Doubtful	Coarse Textured 1/
39.0-48.5	Shale	Doubtful	Fine Textured 2/
48.5-53.3	Sandstone	Suitable	
53.0-74.0	Shale	Doubtful	Fine Textured 2/
74.0-76.0	Shale	Unsuitable	Acidity
76.0-77.0	Coal	Unsuitable	
77.0-103.5	Shale	Doubtful	Fine Textured 2/
103.5-115.0	Shale	Doubtful	Fine Textured 2/
115.0-120.7	Shale	Doubtful	Fine Textured 2/
120.7-125.3	Shale	Doubtful	Fine Textured, 2/ Salinity
125.3-126.8	Coal	Unsuitable	
126.8-129.5	Shale	Doubtful	Salinity
129.5-141.0	Coal	Unsuitable	
141.0-142.0	Shale	Unsuitable	Acidity
142.0-142.4	Coal	Unsuitable	
142.4-158.3	Shale	Doubtful	Fine Textured, 2/ Salinity
	Deep Hole No. RR-5		
0-5.0	Shale	Doubtful	Fine Textured 2/
5.0-8.0	Shale (sandstone)	Suitable	
8.0-77.7	Sandstone	Suitable	
77.7-90.7	Coal	Unsuitable	
90.7-98.1	Shale	Doubtful	Fine Textured 2/

While the materials from 0 to 5.0 feet appear to be doubtful, the sandstone (massive) rock type from 8.0-77.7 feet appears chemically suitable with neutral pH values, low salt, low exchangeable sodium percentages, and adequate cation exchange capacities. However, there will be some problems encountered in the breaking down or weathering of this massive sandstone (hardness up to 6) especially those profiles that are highly cemented, to the consistency needed for revegetation material.

1/ Coarse textured indicates low CEC, high or excessive permeability, limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

Depth (feet)	Material	Evaluation	Remarks
	Deep Hole No. RR-6		
0.0-5.0	Clay and Silt	Doubtful	Salinity
5.0-7.5	Clay and Silt	Unsuitable	Acidity
7.5-12.5	Coal	Unsuitable	
12.5-32.0	Shale	Unsuitable	Salinity, Acidity
32.0-48.1	Shale	Doubtful	Fine Textured 2/
48.1-111.5	Sandstone	Doubtful	Coarse Textured 1/
111.5-137.0	Shale	Suitable	
137.0-138.0	Coal	Unsuitable	
138.0-147.5	Shale	Suitable	

Depth (feet)	Material	Evaluation	Remarks
	Deep Hole No. RR-7		
0-2.3	Soil	Suitable	
2.3-5.0	Sand	Doubtful	Salinity, High SAR
5.0-19.5	Sand	Suitable	
19.5-27.1	Sand	Suitable	
27.1-30.0	Sand	Doubtful	Salinity
30.0-32.0	Coal, Sand, Silt	Unsuitable	Interbedded with coal
32.0-35.6	Shale	Doubtful	Salinity, Acidity
35.6-45.9	Coal	Unsuitable	
45.9-47.9	Shale	Doubtful	Salinity
47.9-54.0	Sandstone	Suitable	
54.0-76.0	Sandstone	Doubtful	Coarse Texture, 1/ Dense
76.0-80.0	Sandstone	Suitable	

In Deep Hole No. RR-7, the sandstone material from 47.9-80.0 feet appears to be suitable chemically for revegetation media, but wherever high cementation occurs, as in depths 73.0-76.0 feet, breakdown into suitable revegetation material will be difficult as exhibited in the weathering study (sample RR-7-18, Results of Weathering Tests).

Depth (feet)	Material	Evaluation	Remarks
	Deep Hole No. RR-8		
0-13.0	Clay	Suitable	
13.0-21.0	Clay	Doubtful	Fine Texture, 2/ Salinity
21.0-37.6	Clay	Suitable	
37.6-48.0	Sand	Doubtful	Coarse Textured 1/
48.0-59.0	Sandstone	Doubtful	Coarse Textured 1/
59.0-114.6	Sandstone	Suitable	
114.6-117.4	Claystone	Doubtful	Fine Textured 2/
117.4-145.0	Sandstone	Suitable	
145.0-160.0	Sandstone	-	0% Core Recovery
160.0-170.7	Claystone	Doubtful	Fine Textured 2/
170.7-190.5	Claystone and Coal	Unsuitable	Fine Textured, 2/ Coal

The depth 145.0-160.0 was not recovered due to the friability of the sandstone and was not outlined on the geologic log.

1/ Coarse textured indicates low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drinage if used on the surface for reclamation purposes.

Depth (feet)	Material	Evaluation	Remarks
		Deep Hole No. RR-9	
0-26.0	Fine Sand and Silt	Suitable	
26.0-28.0	Sandstone	Suitable	
28.0-31.5	Shale	Suitable	
31.5-35.0	Sand	Unsuitable	Coarse Textured 1/
35.0-35.5	Sandstone	Doubtful	Coarse Textured 1/
35.0-37.5	Claystone	Doubtful	Fine Textured, 2/ 2-Inch Coal Seam
37.5-46.0	Siltstone	Suitable	
46.0-53.7	Shale	Suitable	
53.7-57.5	Coal	Unsuitable	
57.5-65.8	Shale	Suitable	
65.8-67.3	Sandstone	Doubtful	Coarse Textured 1/
67.3-72.7	Shale	Suitable	
72.7-82.2	Shale	Doubtful	Fine Textured 2/
82.2-85.7	Coal	Unsuitable	
85.7-94.0	Siltstone	Suitable	
94.0-105.0	Shale	Doubtful	Fine Textured, 2/ Salinity
105.0-118.7	Siltstone	Doubtful	Coarse Textured 1/
118.7-120.9	Coal	Unsuitable	
120.9-127.6	Shale	Doubtful	Fine Textured 2/
127.6-128.1	Coal	Unsuitable	
128.1-150.0	Siltstone	Doubtful	Coarse Textured 1/
150.0-180.2	Sandstone	Doubtful	Coarse Textured 1/
		Deep Hole No. RR-10	
0-3.5	Sand	Suitable	
3.5-18.3	Sandstone	-	0% Core Recovery
18.3-37.5	Sandstone	Suitable	
37.5-39.0	Shale	Doubtful	Fine Textured 2/
39.0-60.0	Sandstone	Suitable	
60.0-63.0	Shale	Suitable	
63.0-93.5	Sandstone	Suitable	
93.5-110.0	Shale	Doubtful	Fine Textured 2/
110.0-117.8	Siltstone	Suitable	
117.8-133.9	Sandstone	Suitable	
133.9-134.5	Coal	Unsuitable	
134.5-143.5	Shale	Doubtful	Fine Textured 2/
143.5-198.3	Sandstone	Doubtful	Coarse Textured 1/

Sample RR-10-9 (39.0-44.0 feet) which is a sandstone (clayey and silty in spots) was tested physically for weathering and exhibited breakdown. Sample RR-10-37 (181.0-188.3 feet) which is a sandstone (fine-grained) exhibited no breakdown during weathering tests, further hindering its suitability for revegetation media.

1/ Coarse textured indicates low CEC, high or excessive permeability, and limited available water-holding capacity.
2/ Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

The weathering tests and greenhouse studies are presented in the appendix of this report, but were considered in the above evaluations.

Wherever suitable soils exist in sufficient quantities, they should be stockpiled and utilized as top priority plant growing material. However, if additional suitable material is needed on the Red Rim area, it could be obtained from the remaining overburden.

Toxic Materials

Elements identified which may be toxic in high concentrations in the overburden materials were limited to sodium and chloride and sulfate salts. Elements are not of the magnitude to be toxic. However, more detailed studies conducted prior to mining may reveal specific toxic materials or others unfavorable for plant growth. If this occurs, these materials must be properly identified and plans made to dispose of them so that planting media and water supplies are not contaminated.

Laboratory Support

Chemical and physical characterizations of genetic soil profiles and bedrock materials were an important aspect of analyzing the material resources of the Red Rim site. Soil samples were taken within the study area. The soil sampling sites are correlated with mapping units and represent typical site chemical and physical characteristics. The bedrock material was obtained from drill borings with the drill cores being received in the laboratory at the conclusion of the field program. The deep boring sites were selected on a geological basis and the drill hole sites became the master sites for characterizing the bedrock material.

The results of these analyses are shown in table C1 in the appendix.

After the drill cores were received in the laboratory, they were separated into samples for bedrock evaluation. The basis of separation included geological characteristics and visually observable characteristics (lensing, staining, cementation, etc.).

Textural composition (fine, medium, coarse, etc.) was also a factor. The majority of the samples are comprised of no more than 5 to 10 feet of the core. A screening technique was used in laboratory characterizations. Pages C12-C15 in the appendix outlines the screenable soil characterizing program followed. The following screening tests were run of all samples: Electrical conductivity in mmhos/cm and pH (1:5 soil water ratio suspensions and $CaCl_2$ .01M), settling volume, fragmented hydraulic conductivity, cation-exhange-capacity, total sodium, and percent moisture at 15 bars. Based on the results of the screenable testing program and field observations, additional analyses were made on those samples which appeared to have deficiencies. These included Na, Ca $\pm$ Mg, and estimated SAR of the 1:5 extract, electrical conductivity in mmhos/cm, Na, Ca + Mg, and SAR of the saturation extract, saturation percentage, and ES. The procedures used are outlined briefly in appendix C. .

In addition to the screenable testing program greenhouse pot studies were made on selected samples to indicate possible toxic or other unfavorable plant growth conditions. Studies are continuing on the plant tissue and soil material to identify growth inhibiting factors demonstrated by the pot studies. With the procedures used in the greenhouse studies, the results do not reflect many adverse physical conditions or nitrogen or phosphorus deficiencies. Results of the pot studies are shown on pages C18-C36 in appendix C.

Representative core sections were exposed to freeze-thaw and wetting and drying cycles to provide an indication of how the geologic material would break down if exposed to the weather. Correlation of these results with actual field conditions is difficult but they do provide an indication. Results of these studies are shown on pages C37 through C44 in appendix C.

SOIL INVENTORY

How This Soil Inventory Was Made

Field work regarding soils investigations began in August 1975, with a reconnaissance of the entire area. The classifiers familiarized themselves with the topography, land forms, and probable complexity of the soils.

Later on, the soils were examined and compared with each other to determine the taxonomic classification. During this period, close contact was kept with the Wyoming Soil Conservation Service to assure that the classification and nomenclature for the study area were compatible with their ongoing mapping in that same vicinity. Profile descriptions that were written, and the aforementioned classification process resulted in a working mapping legend for the soils inventory. Modifications were made to the mapping legend as work progressed to make it more closely reflect the field observations.

Samples for laboratory analysis were taken of representative profiles of all major soil types as well as from deep boring sites. These laboratory analyses facilitated confirming or modifying the mapping legend as well as ascertaining the chemical and physical suitability of the materials for revegetation purposes.

Two kinds of mapping units were utilized to identify the soils. These are soil types and soil complexes. Soil complexes were deemed necessary because many of the principal soils are so intricately associated geographically that it would be impractical and confusing to attempt to delineate each separately, particularly with the scale of aerial photographs used in the soil survey work.

Some of the soils are identified as both a soil type (Rock River sandy loam, 3-12 percent) and as a component of a soil complex (Rock River - Patent fine sandy loam complex). Patent soils in the study area are described as a toxonomic unit, Patent loam, 3-20 percent slope. In the discussion of the complex, the characteristics of the taxonomic member are given only if they vary substantially from those characteristics within the taxonomic unit description. Classification of the soil series in the Red Rim study area is given in Table 11 (Soil Taxonomy 1975).

The standards for soil inventory were essentially consistent with those commonly used by the Soil Conservation Service for a high intensity soil survey. Due to the complexity of the soils in much of the study area, soil complex mapping units were established, necessitating definitions of the taxonomic units as if they had been mapped separately, in addition to a description of the proportional pattern that they make in the complex.

Description of the Soils

This section describes the soil series and mapping units in the inventory area. An important part of the description of each soil series is the soil profile, that is, the sequence of layers from the surface downward to rock or other underlying material. Each series contains two descriptions of this profile. The first is brief and in terms familiar to the layman. The second, detailed, located at the back of the report, and in technical terms, is for scientists, engineers and others who need to make thorough and precise studies of soils. Unless it is otherwise stated, the colors given in the descriptions are those of a dry soil. A summation map showing location and percent of mapping units in area is shown on page 73. Detailed soil profile descriptions and supporting data are on pages C50 through C75 in appendix C. Individual soil inventory sheets are shown as figures C-6 through C-10 in the same appendix.

Cushool sandy loam, 3 to 12 percent slopes (8080) -This soil is moderately deep, well drained, and occurs on narrow ridge slopes and along ephemeral stream channels of the uplands. The dominant slopes are about 5 percent, but ranges from 3 to 9 percent. Other soils which are included in this mapping unit are Delphill which occur on slope-wash material and Worfman which occur on the more level, old erosional surfaces. The surface is brown sandy loam about 3 inches thick and the subsoil is from 15 to 21 inches thick with colors ranging from very pale brown or brown, depending on the amount of fine segregated lime. The texture of the subsoil is a sandy clay loam while the substratum is a calcareous very pale brown to yellowish brown sandy loam. This layer ranges from 8 to 12 inches in thickness. In some profiles examined, the substratum or calcareous sandy loam material was not as deep as that described above.

Permeability and water holding are both moderate and the rooting depth ranges from 22 to 30 inches. Moderate runoff occurs and there exists a slight erosion hazard.

The range of characteristics of this soil includes two mapping units separated on the basis of slope, one unit having 3 to 7 percent slopes comprises about 61.6 percent of this soil type, while the 7 to 12 percent unit comprises about 38.4 percent.

Soil Behavior

This soil is presently used for production of native forage which is fair. No serious limitations are presented in using this soil as plant growth medium in backfilling strip mined lands. Water holding capacity and permeability are both favorable and no adverse effects would be expected regarding the chemical characteristics of the soil.

Havre sandy loam, 0 to 7 percent slopes (8060) - This soil is very deep, somewhat poorly drained and occurs on alluvial fans adjacent to Separation Creek. The slope ranges from 0 to 7 percent, but 4 percent slopes are dominant. Important inclusions are soils of the Monte series which differ in having more homogeneous textures throughout the profile depth and the Debone soils which have a natric horizon and a developed profile of soil horizons. The Monte soils are located on higher edges of fans and are influenced more by deposition from gravity (colluvial) rather than from water.

The surface layer of Havre is normally a fine sandy loam texture, light brown in color and ranging from 2 to 4 inches in thickness. The subsoil is a grayish brown stratified layer containing lenses of silt loam, very fine sandy loam and sandy loam. It ranges in depth from 2 to 24 inches. Substratum are brown silt loams and loams, and extend to 84 inches below the ground surface. Profiles are fairly calcareous and range in pH from 7.6 in the surface soils to 8.6 in the subsoil. Electrical conductivity is moderately high varying from 4 to 16 millimhos/centimeter.

The most important variation from those described above is that the substratum may consist of loamy sand or loamy fine sand material.

Permeability and water holding capacity are moderate, depth of rooting is moderately deep, surface runoff is medium to rapid and the erosion hazard is moderate.

The range of characteristics of this soil includes two mapping units separated on the basis of slope. One unit having 0 to 3 percent slopes comprises about 39.0 percent of this soil type, while the 4 to 7 percent unit comprises about 61.0 percent.

Soil Behavior - This soil is presently used for grazing, and production of native forage is low. The inherent salinity in this soil constitutes the major problem in its use as backfill material. The substratum may also be unsuitable on the basis of low water holding capacity. There may be opportunities however, for mixing with other soils containing more fines, which would increase the water holding capacity to a more favorable state.

Havre sandy loam, 0 to 3 percent slope, alkaline (8100) - This mapping unit differs from 8060 (Havre sandy loam) primarily in that the pH is in excess of 8.8 and ESP is greater than 15 percent.

Soil Behavior - This soil is presently used for grazing, and production of native forage is very low. This soil presents severe limitations for such use due to high sodium levels.

Rockland (8160) - This land type is fairly general in occurrence throughout the study site. Shale rockland represents 55 percent of the mapping unit, sandstone rockland 30 percent, and 15 percent of the areas are shallow soils of the Skootch and Blazon series. Elevation ranges from 6,800 to 7,200 feet and slopes are 10 to 40 percent.

Soil Behavior - This land type is presently used only as wildlife habitat. It is unsuitable as a source of backfill material for use in reestablishing vegetation subsequent to strip mine operations.

Rock River sandy loam, 3 to 12 percent slopes (8070) - The Rock River soils are deep, medium to moderately coarse-textured soils which exhibit good subsurface drainage. This mapping unit occurs throughout the Red Rim area and is fairly extensive. The parent material includes calcareous residual sandy shales and sandstones. They occupy both valley fill and sloping upland positions of 3 to 10 percent slopes, 5 to 7 percent is dominant, however. The aspect of the more modal profiles is northeast. Within the valleys and drainages the aspect is quite variable. Elevations are 7,000 to 7,200 feet. Primary inclusions and their position or occupied landform are (1) Cushool - transistional areas between ridge slopes and valleys, (2) Patent - valley fill and sloping upland fans, and (3) Ryark - valley and uplands in close proximity to the basal sandstone member of the Ft. Union formation.

Typically, the surface layer is a light brownish gray sandy loam, 3 inches thick. The subsoil is about 20 to 24 inches thick, yellowish brown, with textures of sandy clay loam. The substratum is a light yellowish brown calcareous sandy loam and varies from 18 to 30 inches in thickness. This latter horizon contains 15 to 20 percent lime coated gravels. Major variations from those described above are clay loam subsoils and thinner substratums.

The Rock River soils have moderate permeability, and water holding capacity is medium. Roots are found to a depth of 20 to 26 inches below the surface. Surface runoff is medium and the erosion hazard is slight.

Two mapping units of Rock River sandy loam are recognized, and their separation is based on slope, the 3 to 7 percent unit comprising 46.9 percent and the 7 to 12 percent unit comprising 53.1 percent of the soil type.

Soil Behavior - The present use of these soils is for the production of native forage, which soils are good, particularly on leeward slopes or where the soils have received considerable adjacent runoff.

This is one of the deepest soils in the area and thus represents a quantity source of backfill material for use as a plant growth medium. An appreciable difference in water holding capacity exists between the solum and the substratum of this soil. Therefore, the substratum, generally 24 inches and deeper, might be considered for mixing with adjacent soil material having a higher water holding capacity.

Rock River-Patent Complex, 3 to 20 percent slopes (8130) - This complex is about 35 percent Rock River loam, 3 to 12 percent slope, about 30 percent Patent loam, 3 to 20 percent slope, and about 20 percent Cushool sandy loam, 7 to 12 percent slope. The Patent and Cushool soils have profiles described as representative of their respective soil types. The Rock River soils differ from the profile described as representing Rock River sandy loam, in having surface layers of loam and subsoils and substratums which are clay loam rather than a sandy clay loam subsoil and a sandy loam substratum. The Rock River soils which are primarily clay loam in the subsoil section have a higher water holding capacity than those soils identified as the Rock River soils. The acreages of Rock River having clay loam textures is not sufficient to identify as a separate series within the scope of this study.

The Patent soils are formed on recent alluvium, adjacent to the drainage and also on moderate slopes intermediate in position between ridges and drainages. The Rock River soil occupies side slope positions and the Cushool soils are found on convex slopes below the ridges.

Included with these soils in mapping are areas of Delphill soils that make up about 10 percent of the acreage. Also included are areas of Blazon soils that make up about 5 percent of the area.

The Rock River soils are similar to those described in soil mapping unit 8070.

The Patent series is a deep, well-drained soil. It occurs in the southwestern part of the study area. The parent material is local alluvium or slope wash. These soils are found on gentle to moderate slopes, ranging from 3 to 12 percent. Elevations range from 7,000 to 7,200 feet.

The surface layer is pale brown, fine sandy loam about 2 inches thick. The subsoil is brown clay loam about 20 inches thick and is moderately calcareous. The substratum differs from the subsoil in being strongly calcareous. The major variation in this soil type is that some subsoils and substratums are coarse textured, but still within the range of the fine loamy family.

Patent soils are moderately permeable and their water holding capacity is good. Effective depth of rooting is from 20 to 30 inches. Surface runoff is slow on the more gentle slopes and medium on the steeper slopes. The erosion hazard is generally slight.

Soil Behavior - Patent soils are presently used for grazing, and forage production is good. The study deals with the possibilities of reestablishing vegetation subsequent to strip mining operations. Therefore, the suitability of this soil for use in backfill operations and providing a plant growth medium is of primary importance.

Although this soil type is not extensive within the study area, it should be considered as a major source of backfill material. Permeability and water holding capacity are both good. The levels of sodium and salinity are both moderately low and pose no serious problem in reestablishment of vegetation.

Rock River-Ryark Complex, 3 to 20 percent slopes (8140) - This complex is about 40 percent Rock River sandy loam, 3 to 12 percent slope, about 30 percent Ryark sandy loam, 3 to 20 percent, and about 15 percent Skootch sandy loam, 12 to 20 percent. These soils have the profiles described as representative of the identified soil type for each of these soil series. This complex is mapped in drainages which are influenced by materials weathered from sandstone members of the Ft. Union formation. The Rock River and Ryark soils are intermingled in a complex pattern on gentle to moderate side slopes. The Skootch soils occupy the uppermost ridges and slopes.

Included with these soils in mapping are undefined soils similar to Ryark soils in texture and depth to bedrock, but differ because there has been no solum development. These make up 10 percent of the mapping unit. An undefined soil similar to Spool, but differing in that the former is calcareous, makes up about 5 percent. The Rock River soils are similar to those described in mapping unit 8070.

The Ryark series is deep and well drained, and the majority of the acreage is located in drainages which source is from Red Rim Sandstone formations. The parent material is both Lance-Foxhills and Mesa Verde sandstone. The aspect is generally northwest and slopes are from 5 to 12 percent with dominant being 6 percent. The elevation ranges from 7,000 to 7,200 feet.

The surface layer is a brown sandy loam about 4 inches thick. The subsoil is a yellowish brown sandy loam, ranging from 24 to 36 inches in thickness. The substratum is generally a pale brown calcareous sandy loam and about 20 inches thick.

Permeability is moderately rapid and the water holding capacity is fair. Depth of rooting is about 24 inches. Surface runoff is slow and erosion hazard is slight.

Soil Behavior - This soil is presently used for production of native forage which is fairly good. Under the present plant community, the potential for erosion, both wind and water is slight. Regarding the manipulation of this soil, consideration should be given to the use of soil stabilizers or mulching to protect the soil until plant cover can be restablished.

Skootch-Blazon Complex, 7 to 30 percent slopes (8150) - This complex is about 35 percent Skootch sandy loam, 7 to 20 percent slope, about 25 percent Blazon loam, 7 to 30 percent slope, and about 20 percent Rockland. The Skootch and Blazon are intermingled within the mapped areas, primarily ridges and dissected uplands. A minor acreage occurs on steep windward slopes.

Included with these soils in mapping are areas of Delphill soils that make up 10 percent of the acreage and unnamed soils similar to Delphill, but differing in having sandy loam control sections. This unnamed soil makes up 10 percent of the acreage. Runoff is rapid and erosion hazard is severe.

Two mapping units of this soil complex are recognized, based on slope groups. The 17 to 20 percent unit comprises about 59.0 percent of the complex acreage and the 12 to 40 percent unit, about 49.0 percent.

The Skootch series is a shallow, well-drained soil which normally occur on ridgecrests and spur ridges throughout the area. Slopes are gentle to steep and range from 3 to 40 percent. The elevation is from 6,900 to 7,200 feet. These soils formed in residuum weathered from moderately hard sandstone of the Ft. Union formation.

The surface layer of a representative profile is pale brown sandy loam about 2 inches thick. The subsoil is pale brown sandy loam about 15 inches thick. Underlying the subsoil at a depth of 18 inches is a soft calcareous sandstone. Skootch soils are generally calcareous throughout.

Skootch soils exhibit restricted permeability, in place, because of the impervious sandstones which underlie these soils. The soil itself is rapidly permeable, however, and water holding capacity is low. Effective depth of rooting ranges from 14 to 18 inches. Skootch soils experience medium runoff and erosion hazard is slight to moderate.

Soil Behavior - This soil type is presently used for grazing, and forage production is poor. Skootch soils are too shallow and lack adequate water holding capacity for use as stated above.

The Blazon series is moderately well-drained and are shallow to bedrock. Their occurrence in the study area is widespread, but occupy gently sloping to steep sloping ridgecrests and spur ridges. These soils formed in residuum weathered from soft, calcareous, sodic shales and siltstones of the Ft. Union formation. Elevation ranges from 6,900 to 7,200 feet and slopes are generally from 6 to 40 percent.

The surface layer is a brown loam about 2 inches thick. The subsoil is brown calcareous clay loam about 4 to 6 inches thick. The substratum is pale brown calcareous clay loam about 8 inches thick and underlain by soft calcareous, alkaline shaly siltstone. The major variation from those described are in texture of the subsoil and substratum which may be loams or sandy clay loams.

This is a typical profile of a Skootch sandy loam which normally occurs on ridge crests and spur ridges throughout the study area.

Photo 14

Viewing north from south edge of section 18 shows the deep soils of the Patent fine sandy loams which occur in the valley between the steep breaks in the southwestern part of the study site.

Photo 15

Blazon soils have restricted permeability due to shallowness to bedrock, but the soil itself would be considered to be moderately permeable. Available water holding capacity is moderately low. Effective root depth is 10 to 18 inches. Surface runoff is medium to rapid and the erosion hazard is moderate to severe (water) and slight (wind).

Soil Behavior - This soil type is presently used as range, and the production of forage is poor. In relation to its suitability for use as backfill material in reestablishment of vegetation subsequent to strip mining operations, the Blazon soils are judged as unsuitable for such purpose. The low water holding capacity and shallowness to sodic shale are both serious limitations.

Spool-Cothran Complex, 7 to 30 percent slopes (8120) - This complex is about 40 percent Spool loamy sand, 10 to 30 percent slope, about 30 percent Cothran loamy sand, 7 to 20 percent slope, and about 15 percent rock outcrop. They occupy uplands from 7,000 to 7,200 feet elevation. The Spool soil is on sandstone ridges, concave sideslopes, the Cothran soil is in pockets between spur ridges and in leeward slope drainages which source from sandstone formations and the rock outcrop occurs on ridges as ledges and cliffs.

Included with these soils in mapping are areas of Ryark soils which make up about 10 percent of the acreage and soils similar to Spool make up 5 percent. The latter differ from Spool in having calcareous profiles.

The Spool series consist of well-drained, very shallow soils most common to high sandstone ridges within the study area. These soils formed in residuum weathered from hard, reddish yellow-colored sandstones, a basal member of the Ft. Union formation. Slopes range from 12 to 40 percent and the aspect is normally northeast.

The surface layer is pale brown, loamy sand and normally is only about 1 inch thick. The subsoil is pale brown loamy sand, 2 to 3 inches thick. The substratum is yellowish brown, fine sand 5 to 8 inches thick. A hard non-calcareous sandstone is encountered above 14 inches. The entire profile contains no free lime.

Permeability is restricted because of the hard bedrock underlying the sandy soil. Permeability, considering only the soil material is rapid, however, and water holding capacity is low. The rooting depth is 4 to 14 inches. Surface runoff is medium and the water erosion hazard is slight while the wind erosion hazard is considered high.

Soil Behavior - The present use of this soil type is for grazing with a low to fair production of forage. This soil would be unsuitable for use as backfill material in reestablishment of vegetation after strip mining operations because of the reasons given above.

The Cothran series consists of well-drained, very deep soils located on leeward slopes primarily in the central part of the study area. These soils formed on aeolian deposited sands and occur as dunes or deep deposits on gentle to moderately steep slopes. Slope gradient is from 7 to 20 percent. Elevation ranges from 6,800 to 7,200 feet.

The surface layer is pale brown loamy sand which is about 2 inches thick. The subsoil is yellowish-brown fine sand about 30 inches thick. Substratum is brown fine sand and ranges from 15 to 30 inches in thickness. The entire profile contains no free lime, and is neutral. The major variation from those described is in texture of the subsoil which may be a loamy sand. The permeability is rapid and the available water capacity is low.

Effective rooting depth is about 30 inches. Surface runoff is very slight due to the high infiltration rate of the soil. The hazard of water erosion is slight. The hazard of wind erosion is moderate to severe depending on physiographic location.

Soil Behavior - Cothran soils are presently used for grazing, the production of forage being fairly good. The low water holding capacity of this soil type poses a serious problem. The possibility might exist of incorporating this soil with surface layers and subsoils of the Delphill, Cushool or Patent soils. The resultant water holding capacity would be substantially greater and thus may provide a suitable plant growth medium.

Worfman-Delphill Complex, 3 to 20 percent slopes (8110) - This complex is about 40 percent Worfman sandy loam, 3 to 12 percent slope, about 30 percent Delphill fine sandy loam, 7 to 20 percent slope, and about 15 percent Cushool soils. Also included are areas of Blazon soils that make up about 10 percent. This unit is inextensive within the study area. The Worfman soils occupy the gently sloping ridgecrests and Delphill soils occupy the more sloping hillsides. Cushool soils are located in a similar physiographic position to that of the Delphill soils.

The Worfman series consists of shallow and well-drained soils. Because of the shallowness of this soil, its in-place permeability is restricted. Worfman soils are widespread in the study area, but normally occur on gently sloping old erosional surfaces in the uplands and narrow ridge slopes. This soil occupies slopes from 3 to 12 percent. The most common are from 4 to 7 percent and the aspect is variable. Elevation is from 7,000 to 7,200 feet.

Normally, the surface layer is a brown sandy loam, 3 inches thick. The subsoil is a brown sandy loam about 6 to 8 inches in thickness. The substratum is a light brownish gray calcareous sandy clay loam and overlies soft calcareous sandy shale which is encountered above 20 inches.

The permeability, in place, is slow and runoff is medium. Roots are found to the depth of bedrock. Surface runoff is medium and the erosion hazard is slight.

Soil Behavior - Present use of this soil within the study area is for range, with forage production being fair. This soil is shallow and represents a relatively meager source of material for stockpiling and return to the surface at completion of mining operations and prior to reseeding. Other than shallowness of this soil, limitations from other physical and chemical characteristics are not foreseen.

The Delphill soils consist of moderately deep, well-drained profiles which occur throughout the study area on gentle to moderately steep convex slopes, which range from 6 to 20 percent. These soils are forming in residuum weathered from sandy shales and siltstones. Elevations range from 7,000 to 7,200 feet.

The surface layer is yellowish brown fine sandy loam about 3 inches thick. The subsoil is yellowish brown loam and the thickness is from 6 to 12 inches. Substratum is normally brown sandy clay loam, 11 to 18 inches thick. Carbonates have normally been leached from the top 3 inches, but some profiles are calcareous throughout. The most important variation is in texture of the substratum which may range from sandy loam to light clay loam. Available water capacity is medium. Depth of rooting is from 18 to 36 inches. Surface runoff is medium and the erosion hazard is slight on slopes up to 10 percent and moderate on slopes from 10 to 20 percent.

Soil Behavior - Present use of this soil type within the study site is for range, with production being fair to good. This soil in a disturbed or mixed state should possess sufficient water holding capacity and permeability to permit reestablishment of vegetation. No serious limitations are known that relate to the chemical characteristics of this soil. It would be well to note that the deeper Delphill soils occur on the more gentle slopes and a greater quantity of backfill material could be obtained in these areas.

Uses of the Soils - This section is useful to those who need information about soils used as structural material or for other uses. Among those who can benefit from this section are engineers, planners, and farmers.

Table 11 - CLASSIFICATION OF THE SOIL SERIES

Series 1/	Family	Subgroup	Order
Blazon 4/	Loamy, mixed, calcareous, frigid, shallow	Ustic Torriorthents	Entisols
Cothran	Mixed, calcareous, frigid	Ustic Torripsamments	Entisols
Cushool 2/	Fine-loamy, mixed	Borrollic Haplargids	Aridisols
Delphill 2/	Fine-loamy, mixed, calcareous, frigid	Ustic Torriorthents	Entisols
Havre	Fine-loamy, mixed, calcareous, frigid	Ustic Torrifluvents	Entisols
Patent 3/	Fine-loamy, mixed, calcareous, frigid	Ustic Torriorthents	Entisols
Skootch 5/	Loamy, mixed, calcareous, frigid	Ustic Torriorthents	Entisols
Rock River 3/	Fine-loamy, mixed	Borollic Haplargids	Aridisols
Ryark	Coarse-loamy, mixed	Borollic Haplargids	Aridisols
Spool	Mixed, frigid	Lithic Torripsamments	Entisols
Worfman	Fine-loamy, mixed, shallow	Borollic Haplargids	Aridisols

Classification of the Soils - The soils are classified so that we can more easily remember their significant characteristics. Classification enables us to assemble knowledge about the soils, to see their relationship to one another and to the whole environment, and to develop principles that help us to understand their behavior and their response to manipulation. First through classification, and then through use of soil maps, we can apply our knowledge of soils to specific lands and other tracts of land. For additional information about the classification of soils, see Soil Taxonomy 1975. (USDA-SCS Staff. 1975, Soil Taxonomy, Agriculture Handbook No. 436)

1/ SCS, Wyoming - Name - not correlated

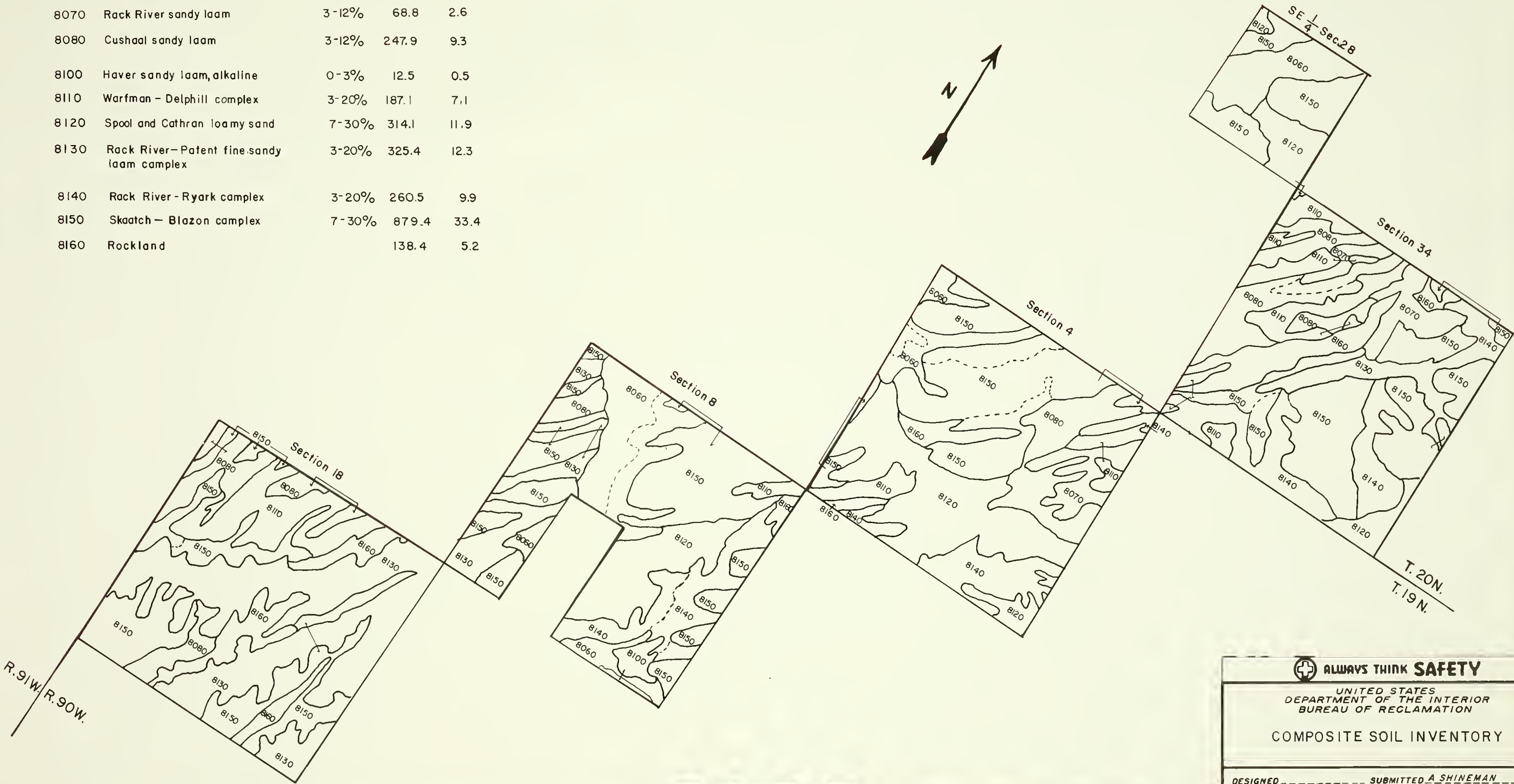
2/ Depth to bedrock in 20 to 40 inches

3/ Depth to bedrock is more than 40 inches

4/ Clay loam texture in control section

5/ Sandy loam texture in control section

MAPPING UNIT NUMBER	NAME	RANGE OF SLOPE	TOTAL ACRES	PERCENT OF STUDY AREA
8060	Havre sandy loam	0-7%	205.9	7.8
8070	Rock River sandy loam	3-12%	68.8	2.6
8080	Cushool sandy loam	3-12%	247.9	9.3
8100	Haver sandy loam, alkaline	0-3%	12.5	0.5
8110	Warfman - Delphill complex	3-20%	187.1	7.1
8120	Spool and Cathran loamy sand	7-30%	314.1	11.9
8130	Rock River-Patent fine sandy loam complex	3-20%	325.4	12.3
8140	Rock River - Ryark complex	3-20%	260.5	9.9
8150	Skaatch - Blazon complex	7-30%	879.4	33.4
8160	Rockland		138.4	5.2



1000 0 1000 2000
SCALE: 1" = 2000'

RED RIM STUDY AREA - WYOMING

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COMPOSITE SOIL INVENTORY

DESIGNED ____ SUBMITTED A. SHINEMAN
DRAWN L. SHANKLIN RECOMMENDED ____
CHECKED T. CAPPELLUCCI APPROVED ____

LM REGION, DEN., COLO.

Vegetation, Vegetation-Soil-Water Relationships, Infiltration and Soil Detachability

Vegetation

The vegetation as mapped on plate 3 can be generally classified as northern desert shrub; all of the sub-types have various mixtures of shrubs, grasses, and forbs. The most extensive and variable vegetation type has big sagebrush as the dominant species. In "blow in" (snow accumulation) sites, the type sometimes has an understory of giant wildrye and total annual vegetation yields exceed a ton per acre (site 1 in table 12). On relatively dry uplands, annual production is less than 400 pounds per acre in this type.

Mixed grasses and shrubs is an extensive type on uplands that is characterized by relatively low productivity (sites 2, 4, and 10 in table 12). Prominent grasses are sandberg bluegrass, western wheatgrass, and bottlebrush squirreltail. Shrubs present include winterfat, nuttall saltbush, and big sagebrush. Average carrying capacity is about 5.4 acres per animal unit month.

Lowest in productivity is the type mapped as threadleaf sedge and mixed shrubs type. This relatively barren type is usually found on relatively steep slopes with stony soils. Drought-tolerant shrubs such as nuttall saltbush, winterfat, and gray horsebrush are present. An estimated 26 acres of this type are required to support one animal unit for one month.

A mixed greasewood-big sagebrush type occurs adjacent to stream channels. Greasewood size and abundance decreases with distance from channels, probably due to increasing depth to ground water. The area covered by this type has a livestock production potential far greater than is present now. It is probable that shrubs have increased and grasses decreased due to past livestock use.

The present flood plain, although limited in area, is the most productive land in the study area. Species present include silver sagebrush, willows, slender wheatgrass, foxtail barley, meadow barley, pidgeon grass, sedges, and rushes.

Of limited extent but important for game animal production is the mountain mahogany type. Other shrubs sometimes found in the type are bitterbrush and serviceberry. The type is usually found on coarse wind-laid soils on upper east-facing slopes where blow-in snow accumulates. Common among the herbaceous understory are threadleaf sedge, Indian ricegrass, and hood's phlox.

EXPLANATION

Big sagebrush. Distribution of this type varies from extensive stands to small, isolated and somewhat circular stands. Included in this type are sites 1, 3, 11, and 7 (see table). The considerable variation in the type is shown by the annual yields which range from more than a ton for a snow accumulation type with giant wildrye to less than 400 pounds per acre.

Mixed grasses and shrubs. An extensive type occupying uplands and characterized by relatively low productivity, sites 10, 2, and 4 (table) are within this type. Characteristic species include winterfat, birdfoot sagebrush, nuttall saltbush and low-producing grasses such as sandberg bluegrass and bottlebrush squirreltail.

Threadleaf sedge and mixed shrubs. A relatively barren type found usually on fine-textured, upland soils (see site 8, table). Drought-tolerant shrubs such as nuttall saltbush, gray horsebrush, and winterfat are present.

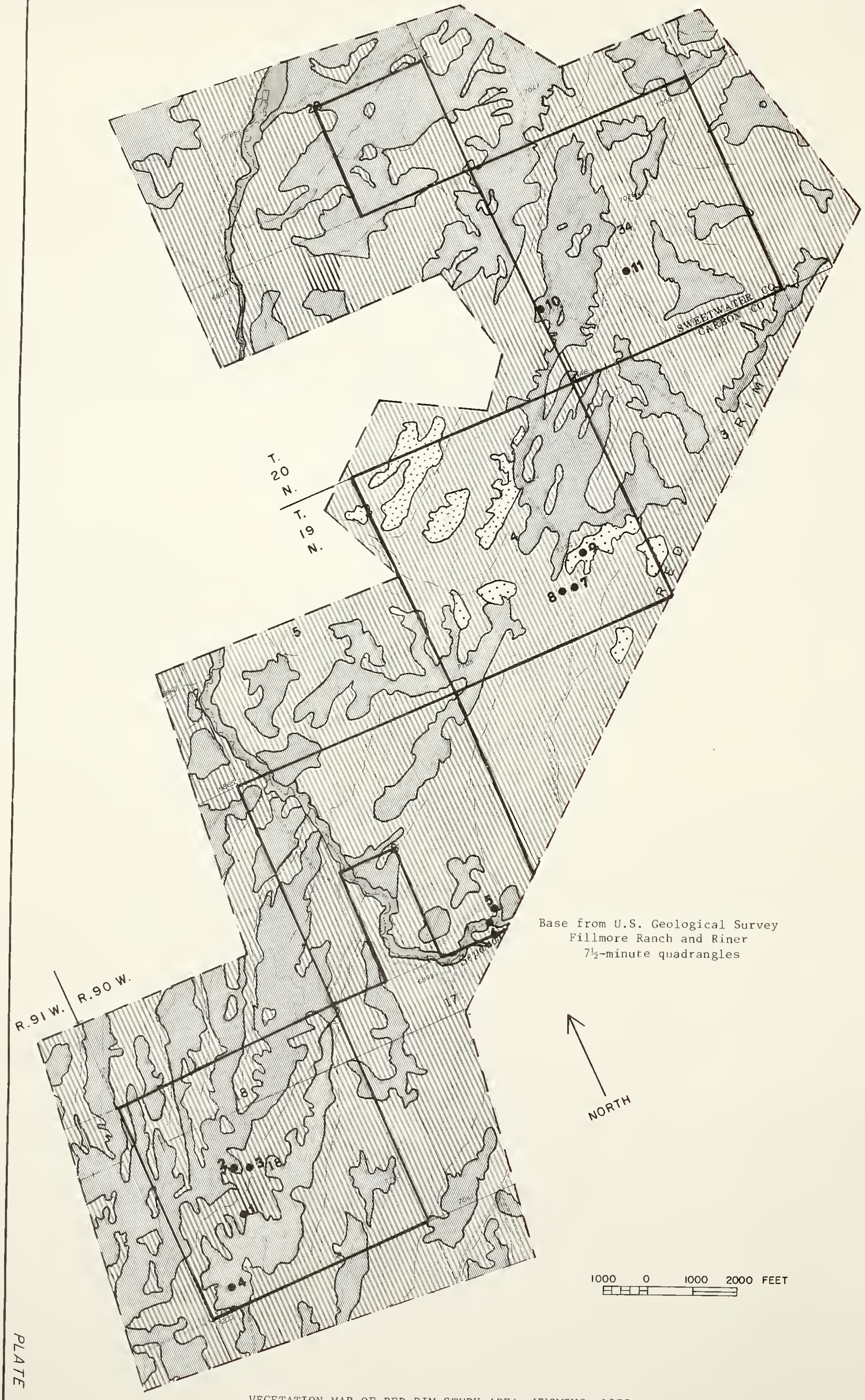
Greasewood-big sagebrush. Because of the indistinct boundary between this type and upland big sagebrush it was included in the big sagebrush mapping unit. It occurs as a narrow to broad band on flood plains above stream channels (site 5 in table).

Mountain mahogany. Of limited extent, this type is found in coarse soils, usually on upper east-facing slopes where blow-in snow accumulates.

Silver sagebrush. This type occurs along the channel of Separation Creek. Other species present include willows, slender wheatgrass, foxtail barley, rushes and sedges.

Locations of vegetation and soil sampling sites.

Study area boundary.



Base from U.S. Geological Survey
Fillmore Ranch and Riner
7½-minute quadrangles

VEGETATION MAP OF RED RIM STUDY AREA--WYOMING, 1975

PLATE 3

Table 1.--Percent cover of vegetation, mulch, bare soil, and rock plus yields of vegetation and mulch. Yields are shown in parentheses

	Vegetation types	Giant wildrye		Winterfat		Big sagebrush		Birdfoot sagebrush-winterfat		Greasewood Big sagebrush		Big sagebrush Western wheatgrass		Threadleaf sedge and mixed shrubs		Mountain mahogany		Mixed grasses and shrubs	
	Site numbers........	1		2		3 and 11		4		5		7		8		9		10	
Shrubs		Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)
Artemisia pedatifida	Birdfoot sagebrush	----	---------	----	---------	----	---------	7.0	(42.0)	----	---------	----	---------	----	---------	----	---------	----	---------
Artemisia tridentata	Big sagebrush	16.0	(879.0)	----	---------	41.0	(325.5)	1.7	(52.5)	26.0	(662.5)	39.6	(208.0)	8.7	---------	----	---------	4.7	(33.0)
Atriplex confertifolia	Shadscale	----	---------	----	---------	----	---------	----	---------	1.3	(105.0)	----	---------	----	---------	----	---------	----	---------
Atriplex nuttallii	Nuttall saltbush	----	---------	----	---------	----	(7.5)	----	---------	----	---------	1.7	---------	5.7	---------	----	---------	3.0	(45.0)
Cercocarpus montanus	True mountain mahogany	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	28.0	(75.5)	----	---------
Eurotia lanata	Winterfat	----	---------	22.3	(337.5)	----	(1.8)	1.3	(76.0)	----	---------	----	---------	----	---------	----	---------	1.7	(52.0)
Grayia spinosa	Spiny hopsage	----	---------	----	---------	----	---------	----	---------	----	---------	7.0	---------	----	---------	----	---------	----	---------
Gutierrezia sarothrae	Snakeweed	----	---------	----	---------	0.7	(54.2)	----	---------	0.7	---------	----	---------	----	---------	4.0	---------	----	(29.0)
Opuntia polyacantha	Plains pricklypear	----	---------	----	---------	0.7	---------	----	---------	----	---------	----	---------	----	---------	0.3	---------	----	---------
Ribes viscosissimum	Sticky current	1.3	(50.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Rosa arkansana	Rose	0.7	(12.0)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Sarcobatus vermiculatus	Greasewood	----	---------	----	---------	----	---------	----	---------	22.0	(435.0)	----	---------	----	---------	----	---------	----	---------
Symphoricarpos oreophilus	Mountain snowberry	4.7	(290.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Tetradymia canescens	Gray horsebrush	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	3.7	---------	4.7	---------	----	---------
Grasses and grass-likes																			
Agropyron dasystachyum	Thickspike wheatgrass	----	---------	----	---------	3.2	(10.8)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Agropyron smithii	Western wheatgrass	----	---------	----	---------	2.7	(27.2)	15.7	(45.5)	5.7	(7.0)	2.0	(102.0)	----	(14.5)	6.0	(7.5)	13.3	(65.5)
Agropyron spicatum	Bluebunch wheatgrass	----	---------	----	---------	1.0	---------	----	---------	----	---------	----	---------	5.0	---------	----	---------	----	---------
Agropyron trachycaulum	Slender wheatgrass	10.0	(42.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Bromus marginatus	Mountain brome	28.7	(40.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Carex filifolia	Threadleaf sedge	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	26.3	(39.0)	4.0	(19.5)	----	---------
Elymus cinereus	Giant wildrye	24.3	(1,083.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Oryzopsis hymenoides	Indian ricegrass	----	---------	----	(2.0)	1.0	(2.5)	6.0	(21.5)	----	---------	----	---------	3.3	(5.5)	5.7	(49.0)	5.3	(4.5)
Poa secunda	Sandberg bluegrass	----	---------	27.4	(29.0)	1.3	(0.8)	1.7	(8.5)	2.7	---------	0.7	(1.0)	----	---------	----	---------	12.7	(7.5)
Sitanion hystrix	Bottlebrush squirreltail	----	---------	2.0	(16.0)	4.2	(17.0)	0.7	(7.5)	3.4	(30.5)	6.3	(3.5)	----	---------	----	---------	3.7	---------
Stipa comata	Needle-and-thread	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	(5.5)	----	---------	----	---------
Stipa viridula	Green needlegrass	1.0	(26.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Unidentified grass		----	(6.0)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Forbs																			
Aster sp.	Aster	----	(20.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Astragalus triphyllus	Tufted milkvetch	----	---------	----	---------	----	---------	----	(7.0)	----	---------	----	---------	----	---------	----	---------	----	---------
Cerastium sp.	Chickweed	----	---------	----	---------	----	---------	----	---------	----	---------	----	(0.5)	----	---------	----	---------	----	---------
Chenopodium alba	Lambs quarters	----	---------	----	---------	----	(3.0)	----	---------	----	---------	----	---------	----	---------	----	(0.5)	----	---------
Erigeron sp.	Daisy	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	0.3	---------
Eriogonum sp.	Wild buckwheat	----	---------	----	---------	0.3	(2.5)	----	---------	----	---------	----	---------	----	---------	----	(13.0)	0.3	(7.5)
Galium boreale	Northern bedstraw	0.3	(16.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Geranium sp.	Geranium	----	(94.0)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Hymenoxys sp.	Hymenoxys	----	---------	----	---------	----	---------	1.0	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Lappula sp.	Stickseed	----	---------	----	---------	----	(0.5)	----	---------	0.3	(1.0)	----	(1.5)	----	---------	----	(58.0)	----	---------
Lepidium perfoliatum	Pepperweed	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Mimulus sp.	Monkey flower	----	---------	----	---------	----	---------	----	---------	----	---------	----	(45.5)	----	---------	----	---------	----	---------
Phlox hoodii	Hoods phlox	----	---------	----	(10.0)	0.2	(17.8)	0.3	(54.5)	----	---------	----	---------	3.0	(6.5)	----	---------	5.7	(440.0)
Sisymbrium sp.	Mustard	----	---------	----	---------	----	(6.0)	----	---------	1.3	(2.5)	0.3	(4.5)	----	---------	----	(7.0)	----	---------
Solidago sp.	Goldenrod	----	(23.5)	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Unidentified forbs		----	---------	----	---------	----	(10.8)	----	(51.0)	0.3	---------	----	---------	1.3	(11.5)	2.3	---------	----	---------
Mulch		13.0	(1,929.0)	17.0	(153.5)	33.6	(1,122.5)	6.0	(98.0)	27.0	(2,936.0)	26.7	(2,064.5)	12.7	(24.0)	13.0	(431.5)	18.7	(242.5)
Bare		----	---------	27.0	---------	9.6	---------	40.3	---------	9.0	---------	13.7	---------	26.3	---------	24.7	---------	23.6	---------
Rock		----	---------	4.3	---------	0.5	---------	18.3	---------	0.3	---------	2.0	---------	6.7	---------	7.3	---------	7.0	---------
Total live cover (percent) and total vegetation yields (lb/acre)		87.0	(2,585.5)	51.7	(394.5)	56.3	(487.9)	35.4	(366.0)	63.3	(1,243.5)	57.6	(366.5)	54.3	(82.5)	55.0	(230.0)	51.7	(648.0)
Estimated carrying capacity in animal unit months per acre			1.6		5.6		6.2		6.2		3.0		7.6		26.1		9.3		4.4

Estimated carrying capacities for each type sampled are shown in table 12. These are to be considered only as "ball park" estimates. A commonly used "rule-of-thumb" considers 50 percent of the annual production available for use by grazing animals. Because of such factors as distance from water and steepness of slopes, 40 percent instead of 50 has been used in these computations. Where significant, additional "cuts" have been made based on species palatability. The average carrying capacity for the study area, based on weighted average of extent of each type, is 6.84 acres per animal unit month. This converts to about 24,608 acres or some 38 sections required to support a ranch with 300 animal units.

Vegetation-Soil-Water Relationships

Water relationships in soils associated with vegetation types that predominate the Red Rim Study Area were studied, first, to define soil parameters essential to the occurrence of natural plant communities, and second, to derive information essential for rehabilitation procedures if coal resources are removed by surface mining. Factors affecting the availability of water are primarily responsible for kinds and amounts of vegetation that occur naturally on these range lands. It is essential to understand these factors if optimum results are to be achieved as a result of rehabilitation efforts.

Soils were sampled within various vegetation types at the 11 sites shown on plate 3. The sampling was done in the summer of 1975 after most of the moisture had been depleted, and that level of moisture was assumed to be indicative of the annual average minimum storage level. The resulting data were used in this report, first, in the development of interpretive relationships, and then in the computation of the amount and availability of soil moisture associated with each of the vegetation types sampled. A table of all data collected is presented in appendix D.

Voids available for infiltration of water to depth in soils are the result of maximum levels of wetting that have been achieved within a period of many years. Void-moisture capacity (VMC) values are computed from volume weight (VW) values, assuming that the average specific gravity of soil particles is 2.65 g/cm^3. This relationship is presented graphically in figure 6. This graph permits approximation of either volume weight or void-moisture capacity if the other value is known. Void-moisture capacity represents the water content of the soil, on a dry weight basis, when it is fully saturated at the existing field volume weight of the soil. Factors that limit levels of wetting achieved with increasing depth are interpreted from void-moisture capacity values.

Table 13

CONVERSION FACTORS

Metric	Multiply by	English
g (grams)	2.205×10^{-3}	pounds
mm (millimeters)	.03937	inches
cm (centimeters)	.3937	inches
dm (decimeters)	3.937	inches
m (meters)	39.37	inches
cm^3, cc (cubic centimeters)	.06102	cubic inches
g/cm^3, g/cc (grams per cubic centimeter)	62.43	pounds per cubic foot
g/cm^2 (grams per square centimeter)	.01422	pounds per square inch
	9.678×10^{-4}	atmospheres
	9.806×10^{-4}	bars
log (grams per square centimeter)	1.0	pF
$kg/m^2/h$ (kilograms per square meter per hour)	1.845	pounds per square yard per hour
	.2049	pounds per square foot per hour
kg/hm^2 (kilograms per square hectometer)	.8924	pounds per acre

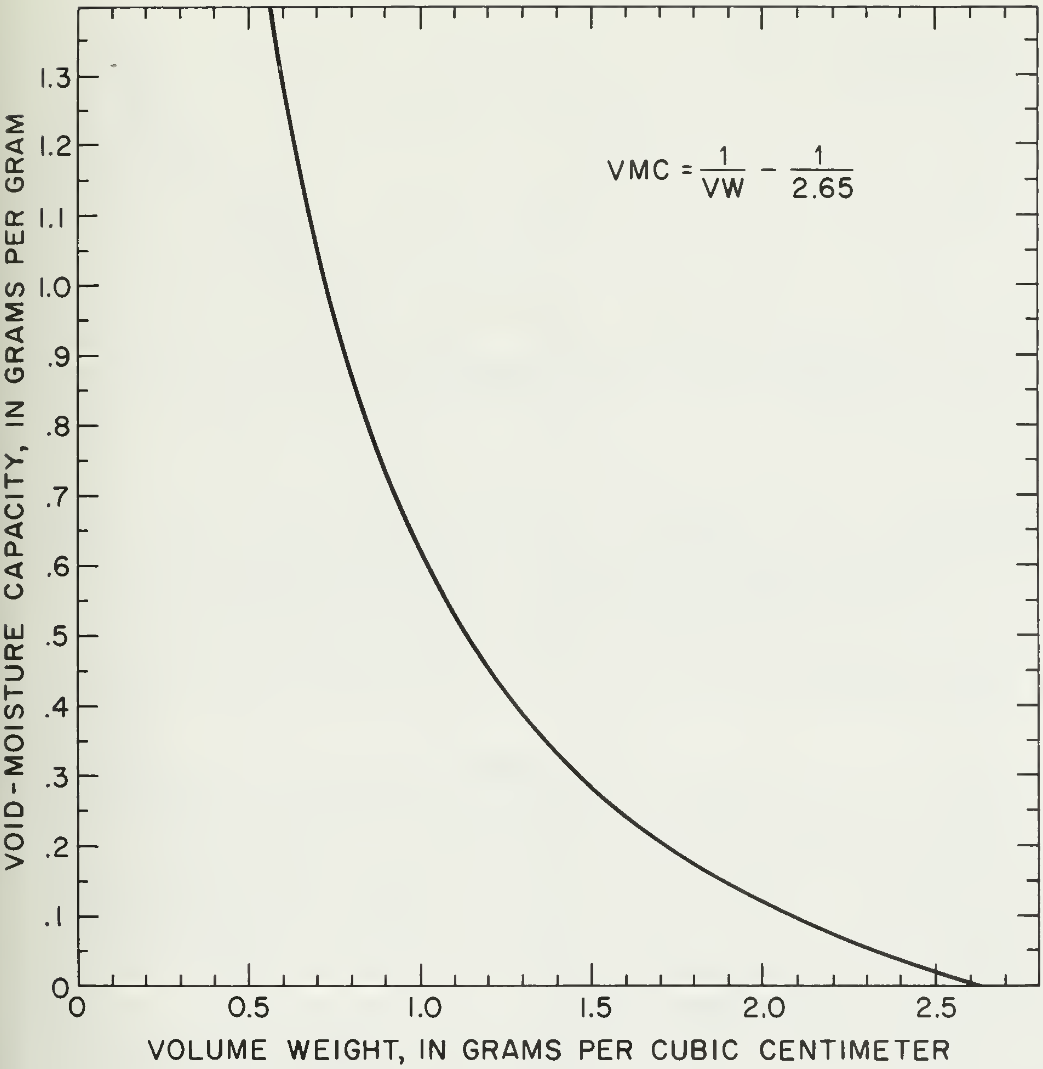


Figure 6 .--Relationship between volume weight (VW) and void-moisture capacity (VMC) of soil.

Moisture-retention capability (MRC) values indicate quantities of water adsorbed to surfaces of soil particles. Moisture-retention capability (MRC) is the water content of the soil when the adsorptive force exerted on the water by the soil particles is 220 g/cm^2 (.22 bar). The concept of moisture-retention capability is similar to that of "field capacity" in that drainage has practically ceased at this retention force, but moisture-retention capability is more specific because it is based on the amount of adsorptive surface in a soil. There is evidence that 10 molecular layers of water are adsorbed (Michurin and Lytayev, 1967) at the moisture-retention capability level (see fig. 7). Under conditions where the moisture content is less than the moisture-retention capability, water is retained only as adsorbed films, with each consecutive film being one molecule thick.

If drainage is impeded, water accumulates in soil, first, as adsorbed films up to a maximum of 16 molecular layers. Water then accumulates as capillary water on top of the adsorbed water until the soil becomes saturated (see fig. 7). After recharge ceases capillary water drains slowly to depth, then the outer six layers of adsorbed water, which are held by small retention forces, are used. The remaining water is held at the moisture-retention capability level.

Water retained by capillary forces can be present to a maximum of 222 cm above a water table or a saturated zone above an impermeable layer. The maximum retention force is $10^{2.34}$ or 222 g/cm^2. For each centimeter in height above the water table the retention force increases 1 g/cm^2. Ten molecular layers of water are adsorbed to particle surfaces at the limit of capillary rise; 16 molecular layers of water are adsorbed beneath water retained by capillary forces 1 cm above the water table.

The mosisture-retention force increases 2.46 times as each of the 16 molecular layers adsorbed to the surface of soil particles is desorbed (removed). The retention force is 1 g/cm^2 when 16 molecular layers are adsorbed increasing to 2.46 g/cm^2 when 15 molecular layers remain adsorbed. The retention force progressively increases to 6.05, 14.89, 36.64, 90.2 and 222 g/cm^2 as the surface of the fourteenth through tenth molecular layers of adsorbed water are exposed. The large magnitude of the last increase in sorption force relative to the previous increases explains why the tendency for water to drain to depth decreases drastically at the moisture-retention capability level.

The fact that the sorption force increases 2.46 times as each consecutive molecular layer of water is desorbed means that the increase in force is proportional or exponential. The exponent or logarithm of the sorption force expressed in g/cm^2 increases by uniform increments of 0.39 as each consecutive molecular layer of water is desorbed (see fig. 7). Expressed exponentially the

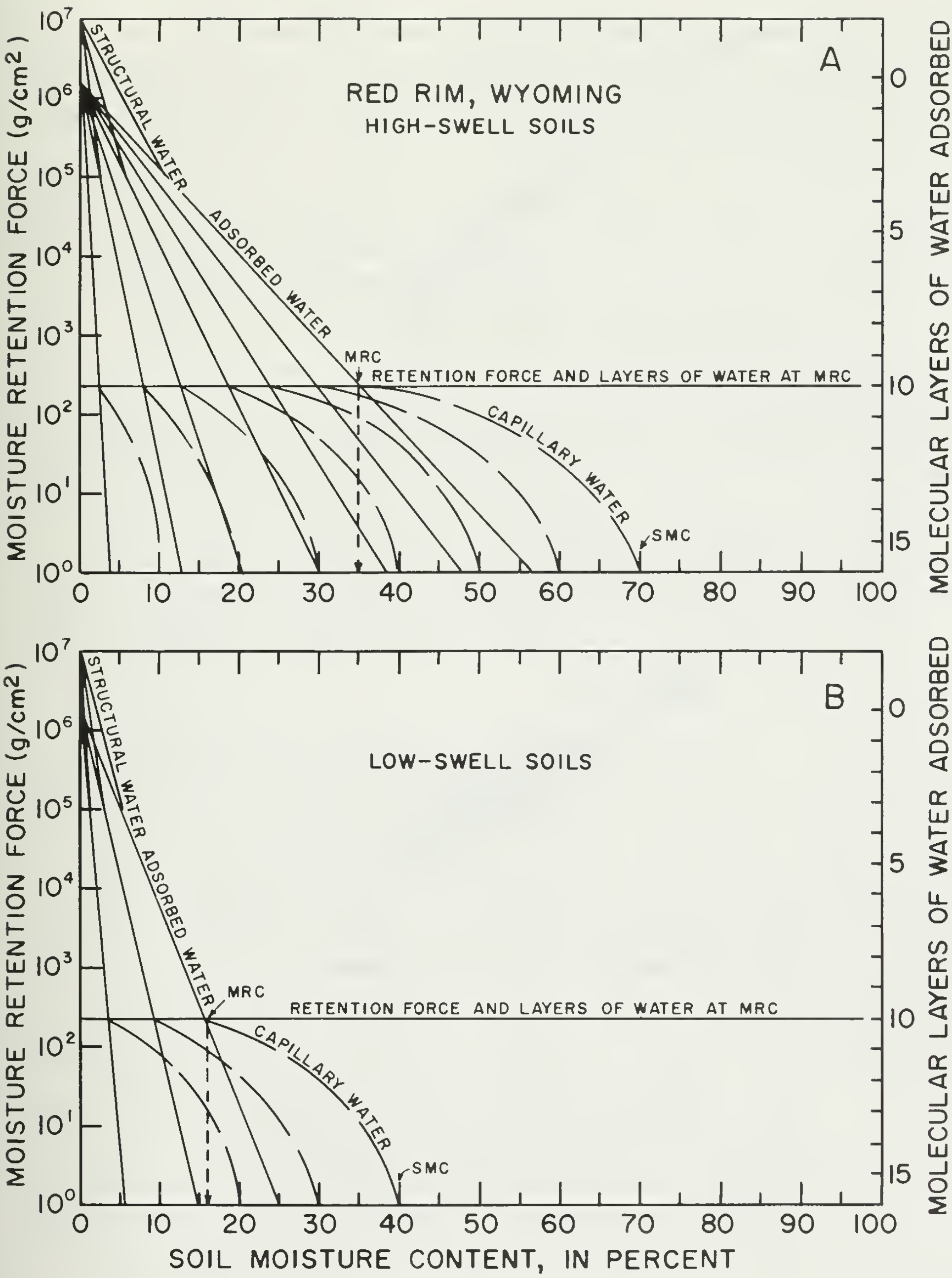


Figure 7 .--Graphic models illustrating moisture-retention characteristics defined for low-swell and high-swell soils. Values for moisture-retention capability (MRC) and saturation moisture capacity (SMC) are indicated for one soil in each group.

sorption force increases progressively from 10^0 to $10^{0.39}$ to $10^{0.78}$ to $10^{1.17}$ to $10^{1.56}$ to $10^{1.95}$ to $10^{2.34}$ as each consecutive molecular layer of water drains off until 10 molecular layers of water remain adsorbed at the moisture-retention capability level.

Moisture-retention forces existing at the time soils were sampled were measured using the wide range "filter paper" method of McQueen and Miller (1968). The retention force or moisture stress is determined from the moisture content of standard filter papers at moisture equilibrium with the soil.

Moisture contents of soils from saturation to oven dryness and the related retention forces can be computed, if the stress at any level where between 3 and 10 molecular layers are adsorbed has been measured, using the graphic modeling technique of McQueen and Miller (1974). Potential quantities of capillary water in excess of adsorbed water can also be approximated if the saturation-moisture capacity is measured. Criteria for saturating soils, prescribed by Richards and others (1954) were used in this study. Saturation-moisture capacity is the water content of the soil on a dry weight basis when all of the voids are filled under unconfined, disturbed conditions.

Moisture-retention characteristics of high-swell soils with saturation-moisture capacity (SMC) values of 10, 20, 30, 40, 50, 60, and 70 percent are illustrated in figure 7A, while characteristics of low-swell soil with saturation-moisture capacity values of 20, 30, and 40 percent are illustrated in figure 7B. Saturation-moisture capacity and moisture-retention capability values used to define these lines were derived from the relationships illustrated in figure 8 . Lines representing adsorbed moisture were extended down from $10^{6.25}$ on the vertical axis through points defined by the moisture-retention force of $10^{2.34}$ g/cm^2 and the water content at the moisture-retention capability of each soil. These lines represent variations in moisture-retention force with variations in moisture contents in the soils. Assuming a change of 0.39 in the exponential value of the force for each layer of water, the number of molecular layers adsorbed to particle surfaces can be discerned (see fig. 7). Variations in moisture contents as capillary forces decrease from the moisture-retention capability level to saturation were approximated by sketching in lines, as illustrated, using a french curve. Quantities of capillary water can vary between the lines representing adsorbed and capillary water (fig. 7). The curved lines represent maximum probable quantities that can be retained by capillary forces.

Soils contain an extra increment of water retained by high levels of stress. This water is contained within the structure of clays, and is, therefore, defined as structural water. Quantities of structural water are approximated by extending lines down from

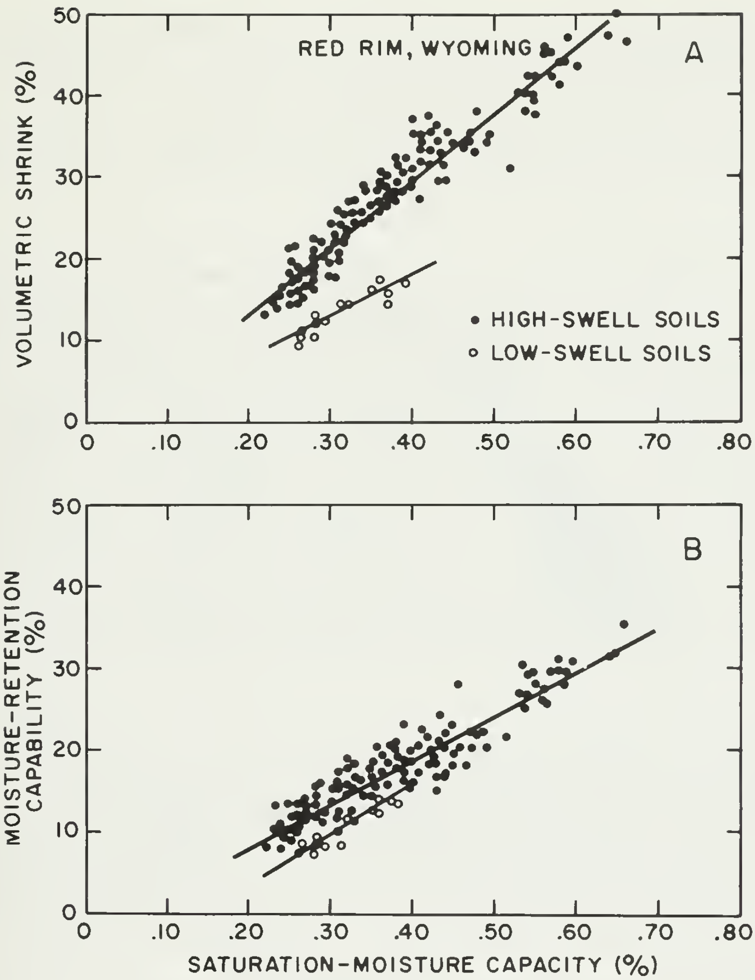


Figure 8 .--Relationships of saturation-moisture capacity to volumetric shrinkage and to moisture-retention capability, indicating two different kinds of soil in the study area.

$10^{7.00}$ on the vertical axis to the point representing moisture content at a retention force of $10^{5.00}$ g/cm^2 on lines representing adsorbed water (fig. 7). As soils dry the water contained within the structure of clays can be depleted. This water must be replenished when soils are rewetted. If this increment of water is not considered in computations, the computations will be slightly in error.

Saturation moisture capacity and volumetric shrink data derived from all but two of the sites plot in a single line designated as representing high-swell soils in figure 8A. These soils probably contain montmorillonitic clay. Data from two sites plot as a distinctly different line with lower swelling and shrinking characteristics relative to saturation-moisture capacity values. These two profiles have developed in windblown sand. It is quite possible that most of the fine fraction containing montmorillonitic clay has been seperated from the remaining coarser materials by wind action. The low-swell materials have more porosity relative to adsorptive surface than the high-swell materials. This is illustrated by the lower moisture-retention capabilities relative to saturation moisture capacities evident in both figures 7 and 8 .

Under field conditions it may be advantageous to approximate moisture-retention capabilities from saturation-moisture capacities, using the relationships presented in figure 9 . If ovens for drying the soil are not available or an immediate answer is required, the saturation-moisture capacity of a sample of soil can be approximated from the volume weight of the saturated material using the linear relationships illustrated in figure .

The relationship between saturation-moisture capacity and moisture-retention capability in figure 8B and the relationship between volume weight of saturated soil and saturation-moisture capacity in figure 9A can be combined to permit approximation of moisture-retention capability from weight per unit volume of saturated soil, as illustrated in figure 9B. Use of this relationship provides a quick means of evaluating moisture-retention capability of soil material under field conditions.

Most of the soil moisture used by vegetation occurring on the study area is derived from snowmelt. Snowfall is possible from mid-September through late May. An average of 149 mm (5.93 in) of precipitation occurs over this period, while only 60 mm (2.38 in) occurs during the frost-free period. Thus 63 percent of normal annual precipitation arrives as snow, while 37 percent arrives as rain over the summer months.

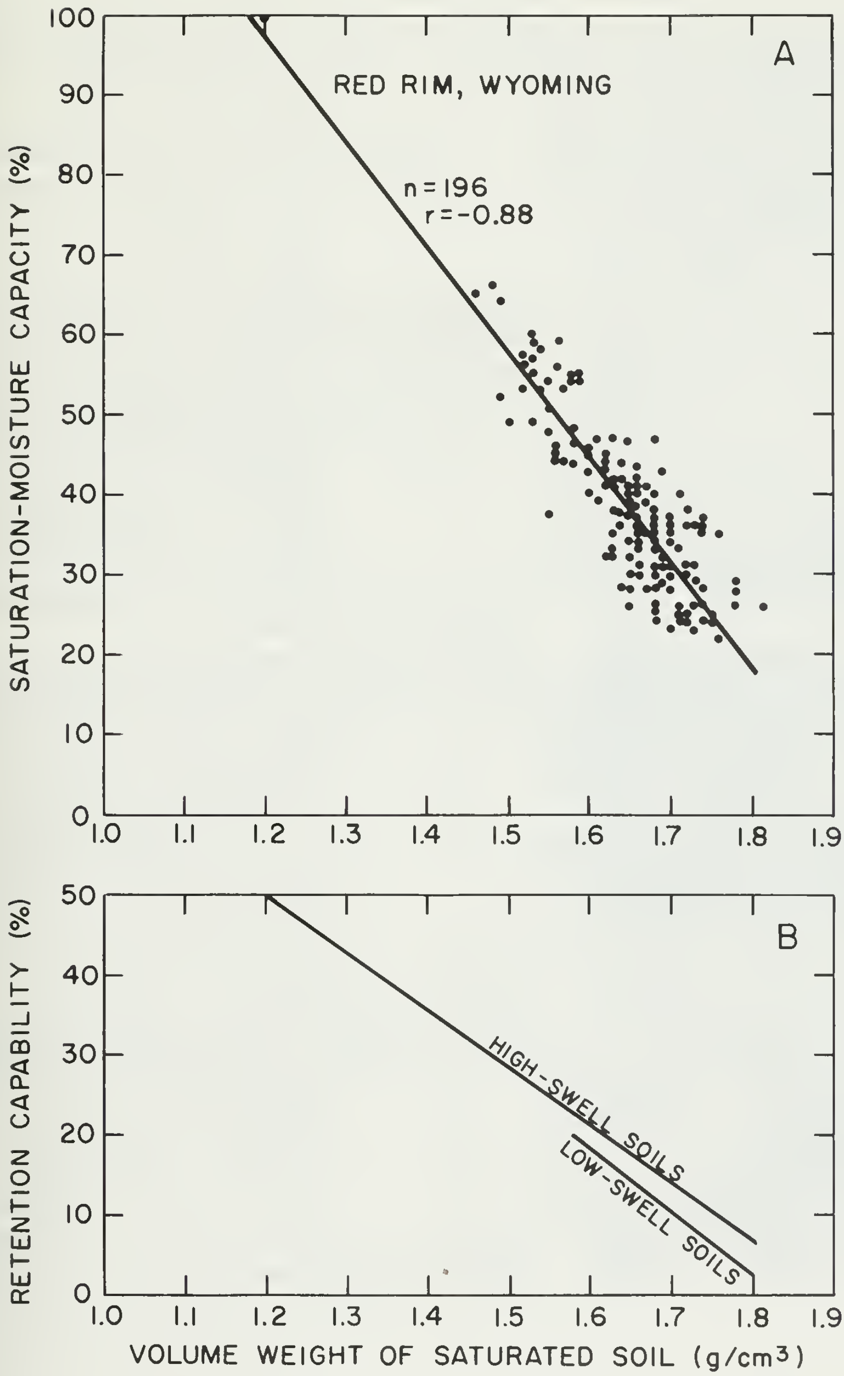


Figure 9 .--Relationships for determining the moisture content at saturation and the moisture-retention capability of soil from the weight of a known volume of saturated soil.

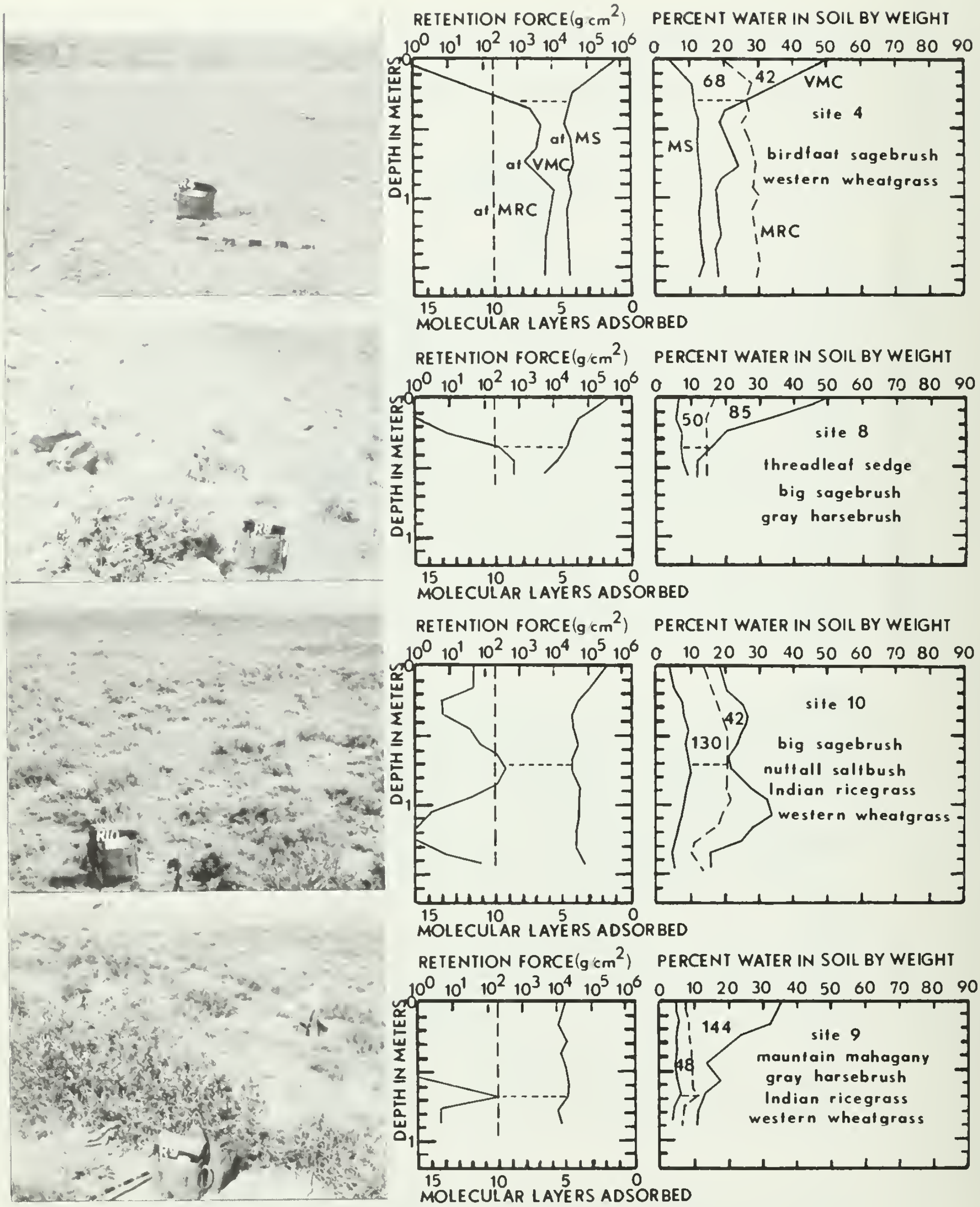


Figure 10.--Photographs and soil-moisture properties of four sites on upland slopes where snow accumulation is minimal. The values within the graphs are computed moisture storage in millimeters.

Maximum levels of water stored in and depleted from soils are computed as the difference between quantities that could be contained at void-moisture capacity (VMC) and at minimum moisture storage (MS). The moisture contents at the sampling time in late July 1975 when the soils were dry were used as estimates of annual minimum storage values. Computations are based on differences measured in the upper horizons where void capacities in excess of retention-capability levels permit drainage of water to greater depths.

Normal soil-moisture storage is less than average annual snowfall; measured at Rawlins, Wyoming; on upland habitats where wind characteristically blows snow away and also where water from rainstorms may run off. Data derived from sites 4, 8, 9, and 10 (see table 12 and plate 3) are typical of upland areas. Photographs of the vegetative aspect and graphs illustrating moisture-retention properties of soil profiles at each of these sites are presented in figure 10 . Void-moisture capacities gradually decrease from the surface to where they become less than the moisture-retention capability at sites 4 and 8, while voids diminish only to the retention-capability level at sites 9 and 10.

Quantities of moisture required to initially fill voids in the surface horizon tend to increase as the retention capability of soils become smaller in progressing from site 4 to site 9 (fig. 10). The main cause for this is an increase in the depth at which the void capacity becomes smaller than the retention capability in progressing from site 4 to site 9. Assuming that amounts of snow accumulation are similar on these sites, the amount of runoff probably decreases in progressing from site 4 to site 9. Grass establishment may be difficult, unless a surface treatment is applied, if the medium- to fine-textured soils associated with the birdfoot sagebrush (site 4), threadleaf sedge (site 8), and mixed grasses and shrubs (site 10) types are replaced on the surface after mining. These soils are in the textural range where reseeding failed after sagebrush eradication (Shown, Miller, and Branson, 1969) but reseeding in areas treated with the Arcadia contour furrower was successful (Branson, Miller, and McQueen, 1966). Sandy soils associated with the mountain mahogany type are quite permeable. They also have the capability of minimizing evaporation. This is indicated by evidence that levels of moisture-retention force increase abruptly as the surface is approached from below in sites 4, 8, and 10 with high to medium moisture-retention capabilities, but not in the dune sand at site 9 (see fig. 10).

Snow and runoff from the uplands accumulates in the valleys, where quantities of water greater than could be derived from normal snowfall are stored in the soil and subsequently evapotranspired. Except for areas with a cover of winterfat, big sagebrush dominates the aspect in areas where snow accumulates. Photographs of the vegetative aspect at valley-located sites 2, 3, 7, and 11 (see

table 12 and plate 3) and graphs illustrating differences in moisture-retention properties of associated soils are presented in figure 11 . Void-moisture capacities exceed moisture-retention capabilities throughout the soil profiles, as a result of the extra moisture received. Spiny hopsage is present with big sagebrush at site 7, where the retention capability of the silty clay soil is high. Shown, Miller, and Branson (1969) also observed that spiny hopsage was an indicator of finer-textured soil. Areas with a cover of spiny hopsage were not amenable to eradication and reseeding. Retention of water on the surface in furrows was required to acquire a satisfactory stand of crested wheatgrass in soils of this textural range (Branson, Miller, and McQueen, 1966).

The presence of winterfat defines areas of medium-textured alluvium. Limiting void-moisture capacities are greater under winterfat than under areas with spiny hopsage. Voids will permit up to 14 molecular layers to be adsorbed under winterfat, but are restricted to 11 molecular layers in areas where spiny hopsage occurs. Drainage to depth is possible when water can be adsorbed in excess of 10 molecular layers, but rates of drainage would be slower where there are smaller voids.

Void-moisture capacities exceed the adsorption-moisture capacity limit of 16 molecular layers in areas where almost pure stands of big sagebrush predominate. This occurs at site 3 on soil that characteristically would have a cover of winterfat. Sagebrush occurs there because of the infiltration of water that runs in from upslope. Run-in water is not essential for the occurrence of sagebrush on sandy loam soils with lower retention capabilities, as is illustrated by data for site 11. Moisture derived from entrapped snow which blows off higher areas provides the essential moisture in these areas. The placement of these soils in the valleys of the reshaped landscape following mining would retain the benefits of snow accumulation. In these soils where voids exceed the adsorption capacity of 16 molecular layers, water drains to depth more readily. Under these conditions it is assumed that decreases in void capacity with depth indicate the wetting gradient of each soil. Areas dominated by big sagebrush with sandy loam soils should be amenable to seeding with crested wheatgrass or native grasses without furrowing (Shown, Miller, and Branson, 1969).

Greasewood occurs with big sagebrush on deep alluvium at site 5 (plate 3 , table 12 , and fig. 12) adjacent to the channel of Seperation Creek. The amount of soil-moisture storage is insufficient to account for the amount of plant cover. Roots from greasewood can penetrate to great depths to obtain ground water and were still present in significant quantities at a depth of 4.8 meters at this sampling site. The alluvium associated with this type is a sandy loam to loam in texture. It has a high pH indicative of the presence of sodium concentrated by greasewood, and is rather

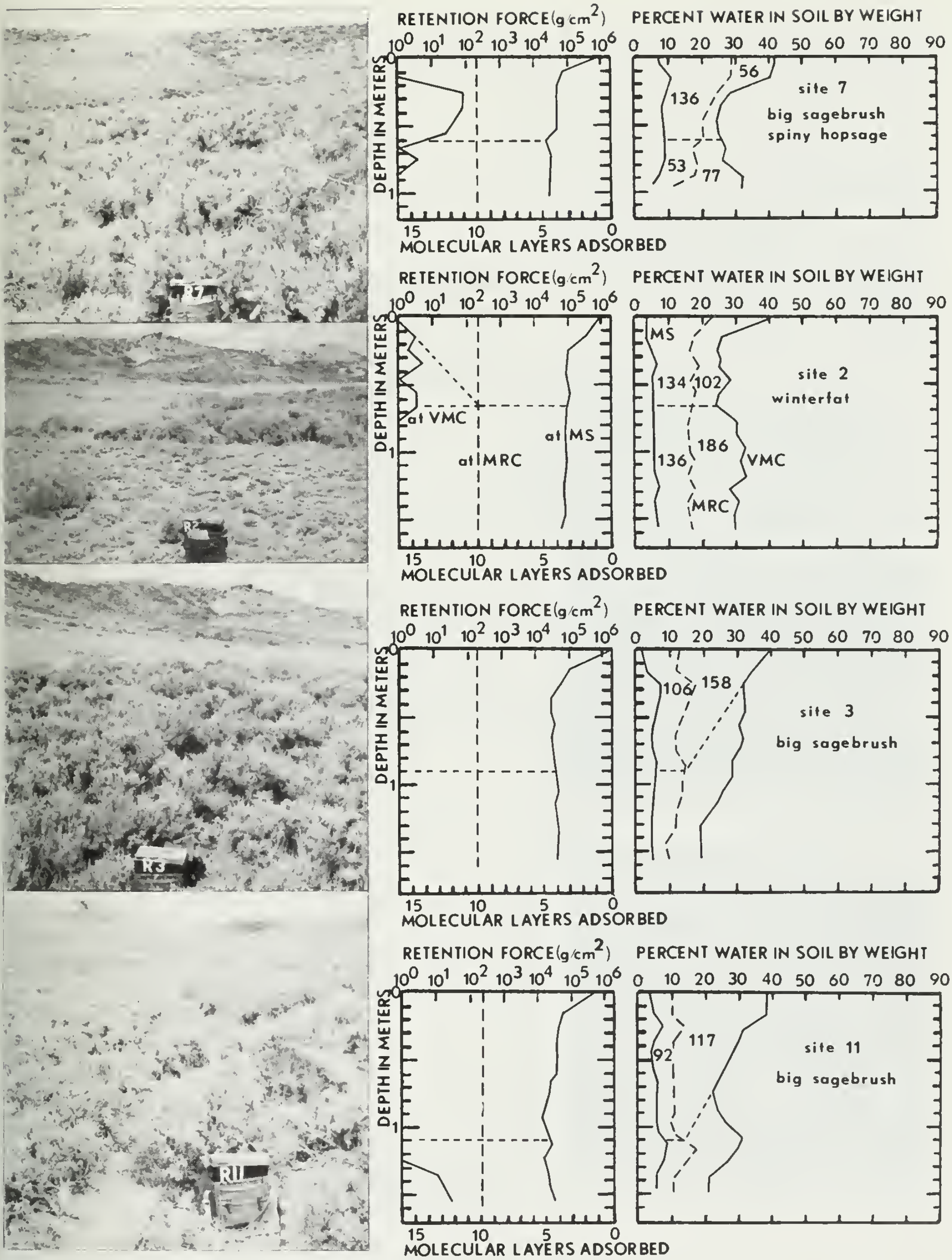


Figure 11.--Photographs and soil-moisture properties of four sites where snow accumulates in upland valleys. The values within the graphs are computed moisture storage in millimeters.

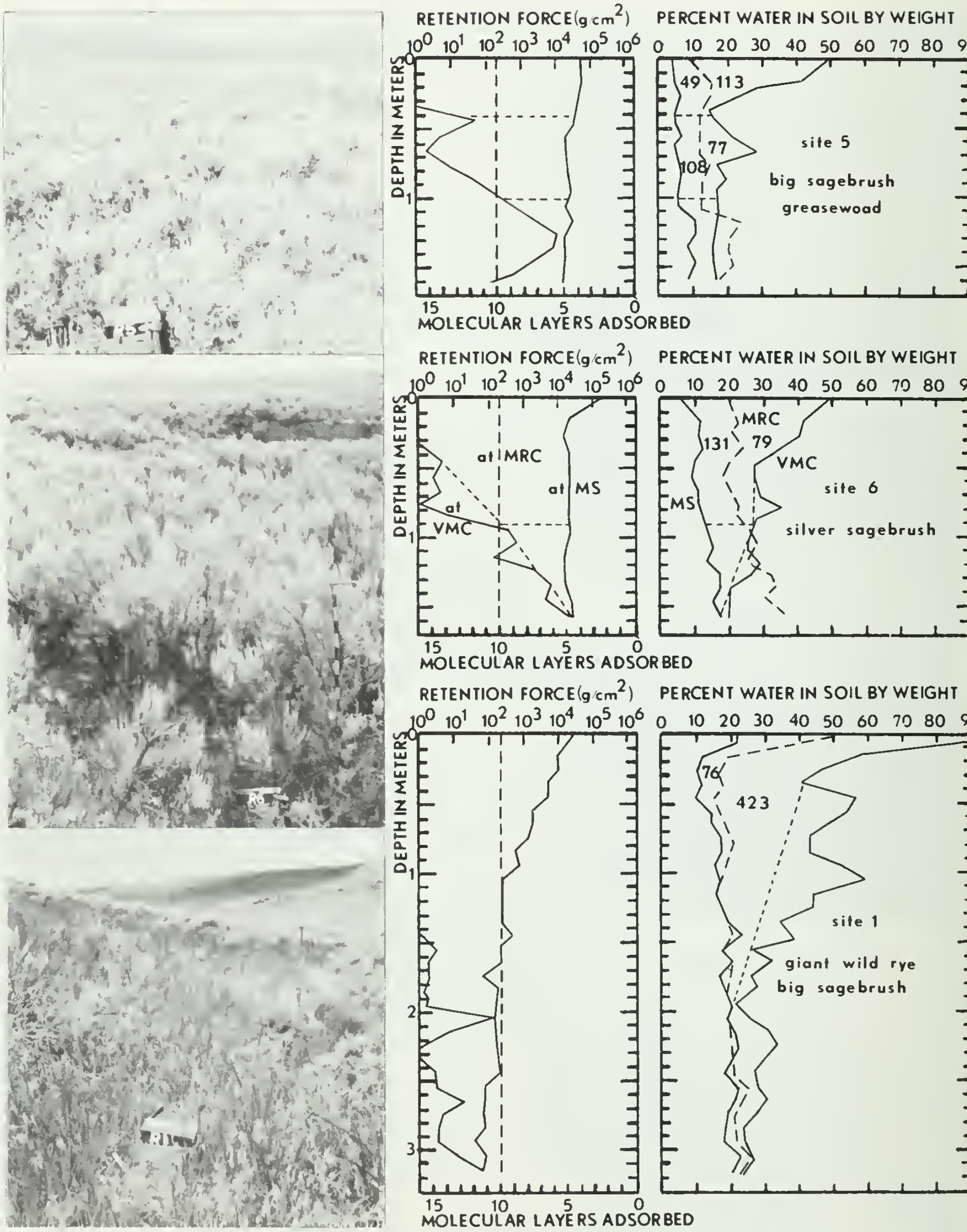


Figure 12 .--Photographs and soil-moisture properties of three sites where moisture is plentiful. The shrubs at sites 5 and 6 utilize ground water from alluvium in addition to soil moisture. Deep accumulation of snow during winter is the apparent source of soil water at site 1 which is highly productive. The values within the graphs are computed moisture storage in millimeters.

saline, but because of the texture, both sodium and salt could be leached out of the material. Application of gypsum to the surface would insure replacement of adsorbed sodium with calcium and improved soil structure. Deposition of 2 feet of this relatively coarse material over finer-textured soil would result in adsorption of water in excess of the retention-capability level of 10 molecular layers. Energy required to desorb water from the 11th, 12th, or 13th layer adsorbed is lower than where ready drainage to retention-capability levels can occur. As a result more vegetation cover and forage can be produced per unit of water stored under these conditions.

The flood plain of Seperation Creek is occupied by a stand of tall silver sagebrush with an understory of grasses (site 6, fig. 12). Here again soil-moisture storage does not account for the productivity of the site, so use of ground water in addition to soil moisture is assumed. Some layers of alluvium of the flood plain are moderately fine textured and may require a surface treatment to retain runoff water if used for rehabilitation on nonflooded sites.

Site 1 (plate 3 , table 12 , and fig. 12) was the wettest and most productive site sampled. It occurs in the lee of a steep slope where huge quantities of snow apparently accumulate. Void capacities in this medium-textured soil diminish to the retention-capability level at a depth of 2 meters in this profile, as compared to shallower depths in the other two sites illustrated in figure 12 . Storage of water in excess of retention-capability levels is quite evident, because of the magnitude of void-moisture capacities, and because depletion beyond retention-capability levels is quite minimal. This type provides evidence that productivity of the area could be increased by reshaping the land to influence the accumulation of snow after mining. The site also provides evidence of the increased productivity that can result from moisture stored as loosely adsorbed films in excess of retention-capability levels.

A linear relationship between live vegetation cover and quantities of water depleted between maximum void-moisture capacity and minimum levels of storage is presented in figure 13 . There was sufficient data available from the sites sampled in the Red Rim Study to indicate that a linear relationship existed. Data from the Hanna and Potter Mountain EMRIA Study Areas was included with data from Red Rim to define a linear relationship that would be applicable most places in the Wyoming Basin where snow is the primary source of soil moisture.

The millimeters of water normally depleted from a soil can be computed as 7.19 times the percent cover minus 177, or by use of the graph in figure 13 . The "r" value for the relationship is

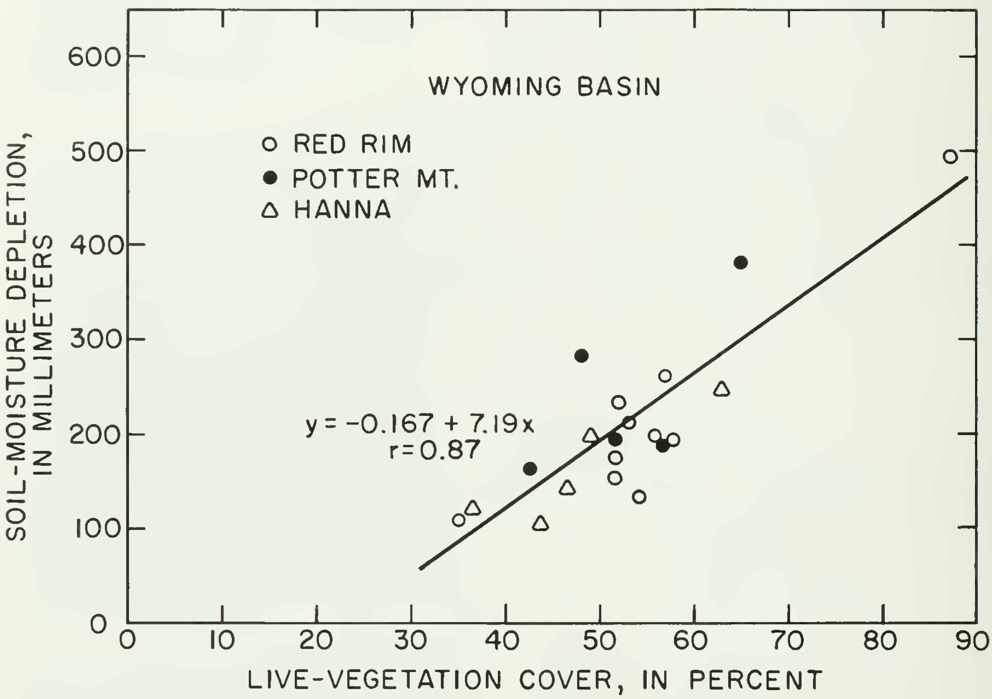


Figure 13 .--Relationship of live-vegetation cover to the quantity of water depleted from soil between maximum and minimum storage levels.

0.87, so the quantity of water stored in the soil is a major factor in determining the amount of cover. Estimates of soil moisture storage in similar areas could be made by applying BLM Watershed Conservation and Development System Phase 1 cover data in this relationship. If adequate precipitation information is available, runoff potential could be computed by taking the difference between annual precipitation and annual soil-moisture depletion. Carrying capacity data as well as cover data can be used to determine the efficiency with which the water resource is used under premining conditions as compared to post-rehabilitation conditions.

Data in figure 14 shows that salt-desert shrubs have a greater capability for removing water from soils than northern desert shrubs. Both groups of shrubs occur on the Red Rim Study Area, but some of the points represent data from the Hanna Basin and Potter Mountain EMRIA Study Areas. Species in the salt-desert shrub group are nuttall saltbush and winterfat. Species in the northern desert shrub group include big sagebrush, birdfoot sagebrush, gray horsebrush, spiny hopsage; and the mountain browse species, true mountain mahogany. Because salt-desert shrubs can exert more force per unit of water extracted from the soil, they occur on drier sites where runoff is appreciable or snow accumulation is meager. Salt desert shrubs can deplete moisture to where only three molecular layers of adsorbed water remain, while the northern desert shrubs deplete water to where four or five molecular layers remain.

Data from the Red Rim Study Area in table 14 indicates how the amount and availability of soil moisture at a site affects the kind and number of vegetation species occurring on that site. Low-growing shrubs and grasses occur on sites where the most force to desorb water was required. The number of species tend to increase as the force requirements decrease with a corresponding shift toward species with greater water requirements. Taller shrubs and grasses are present as force requirements diminish. Tall grasses predominate on site 1 where soil moisture is most plentiful and is retained at low forces.

Relationships between the quantity of soil water and the force or energy requirements for desorbing the water can be manipulated to change the species mix, increase forage production or decrease a hydrologic response such as runoff or erosion. In any given soil, force requirements per unit of water desorbed can be decreased by increasing the amount of water stored in the soil. This can be achieved when reducing runoff by contour furrowing or some other biological or mechanical treatment of the surface soil or the vegetation. It could also be achieved by influencing snow accumulation by shaping the soil surface, using drift fences or by planting vegetation that traps snow. Energy requirements can also be reduced by placing a layer of coarse soil over fine soil, which will result in perching of water at levels of stress less than retention-capability levels.

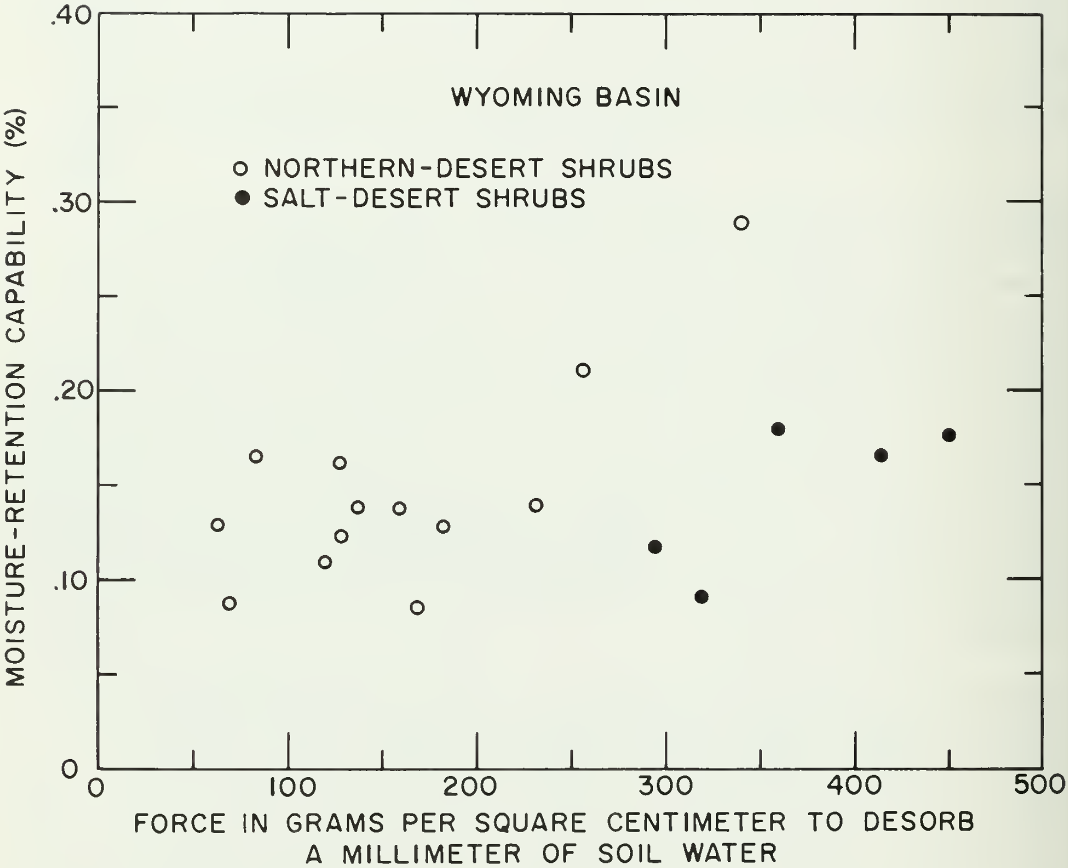


Figure 14 .--Diagram showing that salt-desert shrubs have a greater capability for extracting water from the soil than northern-desert shrubs.

Table 14 .--Diversity of species in the Red Rim Study Area as affected by average force required of vegetation to remove water from the soil. X indicates presence of a species.

Site number	2	10	4	7	3	8	11	9	1
Force required ($g/cm^2/mm$ of water)	414	359	338	255	181	159	120	70	0.73
Winterfat	X	X	X						
Sandberg bluegrass	X		X	X	X		X	X	
Bottlebrush squirreltail	X		X	X	X		X		
Nuttall saltbush		X		X		X			
Big sagebrush		X	X	X	X	X	X		X
Indian ricegrass		X	X			X			
Western wheatgrass		X	X		X		X	X	
Birdfoot sagebrush			X						
Gray horsebrush				X		X			
Spiny hopsage				X			X	X	
Bluebunch wheatgrass						X	X		
Threadleaf sage						X			
Snakeweed							X	X	
Thickspike wheatgrass							X		
Tree mountain mahogany								X	
Plains prickly pear								X	
Sticky current									X
Rose									X
Mountain snowberry									X
Slender wheatgrass									X
Mountain brome									X
Giant wildrye									X
Green needlegrass									X

Infiltration and Soil Detachability

Soil erosion and sediment production involve the interaction of two sets of forces. One set of forces, the erosive agents, cannot be forecast for any given time period at a given site except as probabilities based on past records. The other set of forces, the ability of the soil to resist the actions of the erosive agents, can be defined by properly designed laboratory and field tests.

Detachment and transport of sediment in runoff can occur only when the rate of rainfall (or snowmelt) exceeds the rate of infiltration. Therefore, the infiltration rate of the soil becomes a definable parameter of the erosive forces. If infiltration relationships are known, estimates can be made for the magnitude of storm that will produce runoff and erosion.

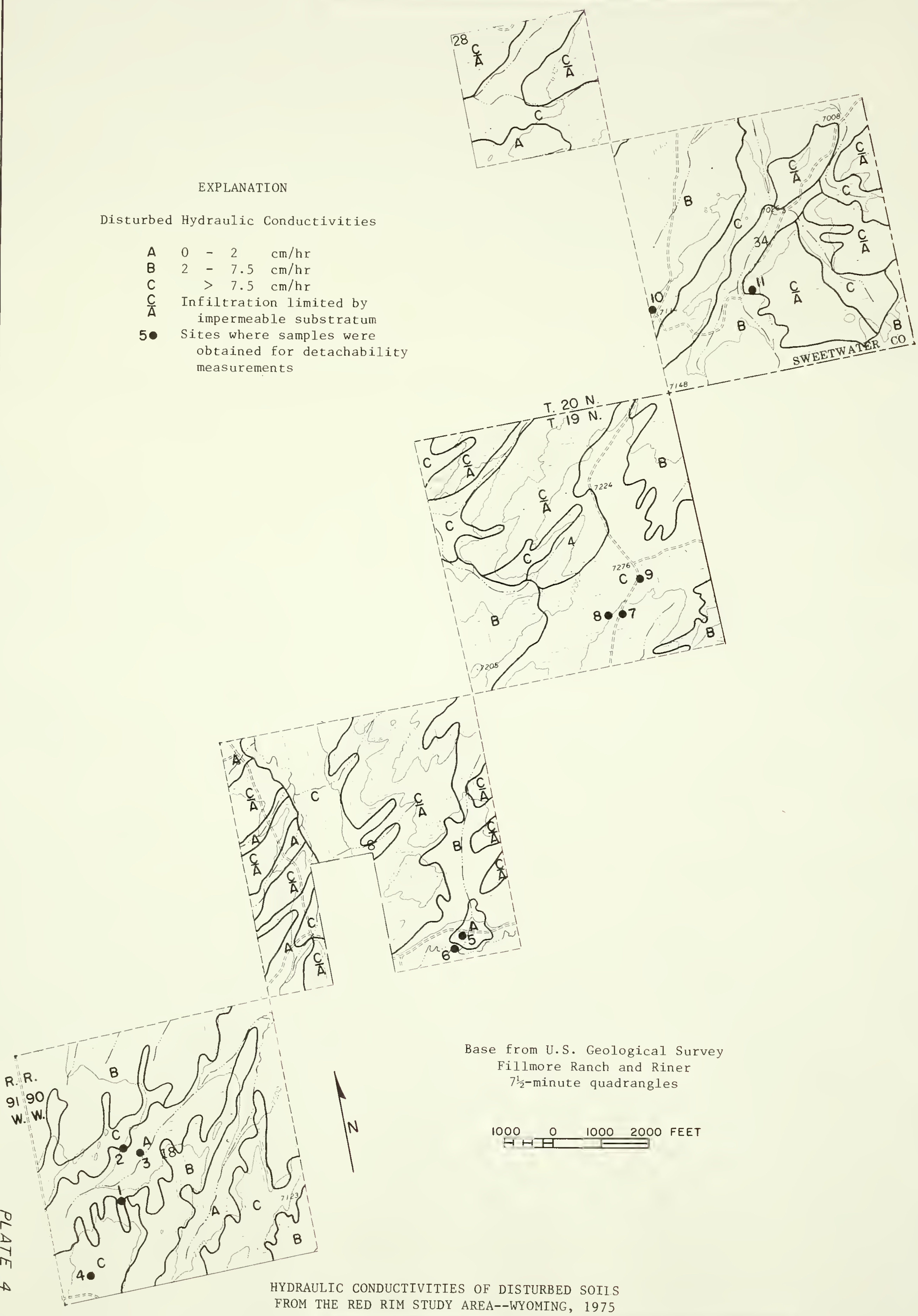
Infiltration rates on mined areas will be different from rates measured on undisturbed areas under native vegetation. Soil structure and root channels that aid infiltration will be destroyed and pososities of the soils will be reduced because of packing by machinery used to replace and reshape the soils. As new vegetation becomes established during the rehabilitation period, normal infiltration rates may gradually be restored.

Fragmented hydraulic conductivities, reported in appendix (Soils), on pages C-6 through C-11, are indexes of disturbed hydraulic conductivity rates. Areal distribution of hydraulic conductivity classes are shown on plate 4. These are based on measurements on cores from the various soil-mapping units shown on figures C-6 through C-10, also in the appendix (Soils).

Infiltration rates of the surface soils are high, with the exception of those in Class A on plate 4 . The soils in Class $\frac{C}{A}$ have restrictions to permeability within the profiles indicating that runoff may be excessive during intense rainstorms or prolonged snowmelt.

Detachability of soil particles is influenced by depositional sequences and soil-forming processes. Humic surface soils are less susceptible to erosion than deeper soil horizons with less humus and lower root concentrations. Clay horizons, deposited by soil-forming processes or by alluvial sequences, have low susceptibility to erosion. Fine sands and silts are susceptible to erosion when they are not stabilized by vegetation.

Susceptibility of soils to erosion by flowing water was determined in the laboratory by subjecting samples to controlled erosion forces and measuring the rates of detachment (McQueen, 1961). This procedure does not predict actual sediment production from the wide range of erosion events that occur at a site but it does



HYDRAULIC CONDUCTIVITIES OF DISTURBED SOILS
FROM THE RED RIM STUDY AREA--WYOMING, 1975

PLATE 4

define relative detachability of individual soil samples. Remolded samples were used in these tests to simulate the disturbed conditions of the soils that would prevail during mining and rehabilitation.

Detachability data for samples from soil and vegetation sampling sites are shown in figure 15 and are also listed in table D1 in the appendix. Site 1, with a productive cover of giant wildrye, has the least erodible soil. Organic-matter cementing of aggregates and greater root concentrations appear to be the reasons for the lower detachability rates in the upper 0.5 meter of that soil. Soils of sites 2, 3, 7, and 10 are moderately erodible. Detachability rates increase for samples that were from depths below about 1 meter in those soils.

The soils of sites 4, 9, and 11 are highly detachable (fig. 15). The soil at site 4 is moderately fine-textured, and the soils at sites 9 and 11 are moderately coarse-textured. Detachability rates are lower for the upper 0.2 meters of the site 11 soil, probably because of greater root and organic matter concentration.

Sites 5 and 6 are on alluvium near Separation Creek. Detachability rates are relatively low near the surface but vary erratically with depth on these sites. This is apparently due to minor variations in texture between successive layers in the deposits.

Detachability rates are low for the upper two samples of site 8 but increase drastically for the samples from greater depths (fig. 15). This illustrates the soil-binding effect of shallow-rooted, sod-forming vegetation.

If the area is mined, erosion during the rehabilitation period could be reduced by utilizing the present surface soils as top dressing. Some form of surface treatment such as contour furrowing with check dams (Branson, Miller, and McQueen, 1966) or gouger pitting (Sindelar, and others, 1974) may be required for erosion control on sandy areas steeper than about 10 percent and on all areas topped with fine-textured materials, regardless of slope.

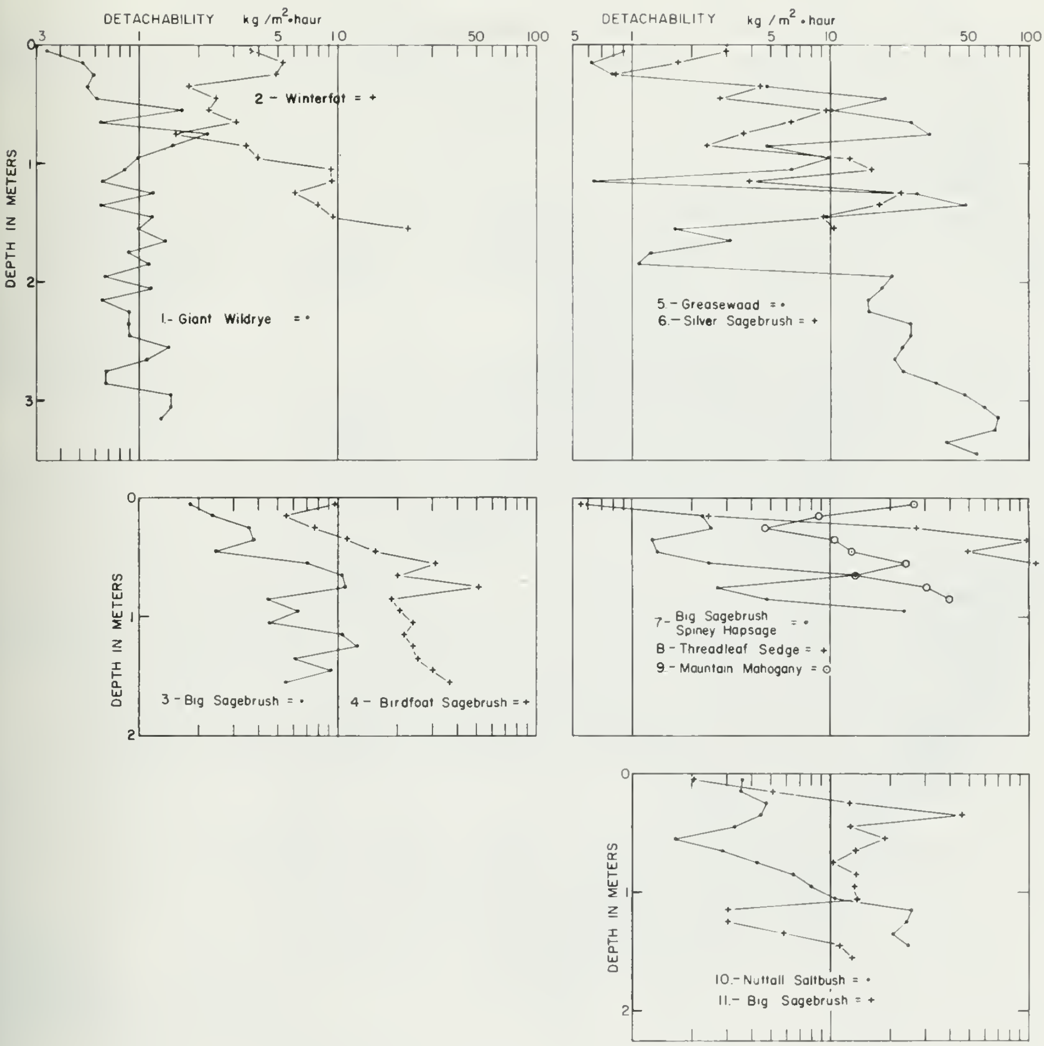


Figure 15 .--Graphs showing variations with depth of soil detachability rates as measured in flowing water. Locations of the sites are shown on plates 3 and 4 .

Sediment Yields

Procedures

The sediment-yield information presented in this section was derived using the PSIAC (Pacific Southwest Inter-Agency Committee) (1968) method. Experience indicates that the values are reasonable, but their accuracy has not been verified by measurements.

The mapping unit that is the basis of this sediment-yield evaluation is the source area. A source area is defined as a relatively homogenous watershed area that is only a part of a complete drainage basin. The primary factor used in delineating a source area is landform type. Other factors considered are vegetation type and density, slope gradient, drainage density, and sometimes surficial geology. These factors are assigned numberical ratings during the mapping process in order to assess the hydrologic variation for the given landforms and to provide input for the PSIAC ratings.

Nine factors are rated when using the PSIAC method: surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, channel erosion, and sediment transport. The method was developed to make broad sediment-yield classifications for large areas, such as river subbasins, but Shown (1970) found that method provides reasonable estimates for small drainage basins. In applying the method on source areas some adjustments are made because a complete drainage system is not being considered. Fan and floodplain development are not considered in the topography factor and sediment transport capabilities are not considered for channels that originate in upslope source areas and that cross through the source area being rated. These factors are taken into account by the sediment-conveyance factor, which is multiplied by the weighted average source-area sediment yield to obtain the sediment discharge from a drainage basin.

Interpretations of false-color aerial photographs (1:12,000 scale) were used to extend the source-area sediment-yield estimates to those areas that were not actually rated in the field. This resulted in the source-area sediment yield map shown on plate 5 . The slope data were obtained from the 1:24,000 U.S.G.S. topographic quadrangles. The percentage of bare soil was measured by the first contact-point method within selected vegetation types on the site, and estimates were made for the remaining types with the aid of the aerial photographs.

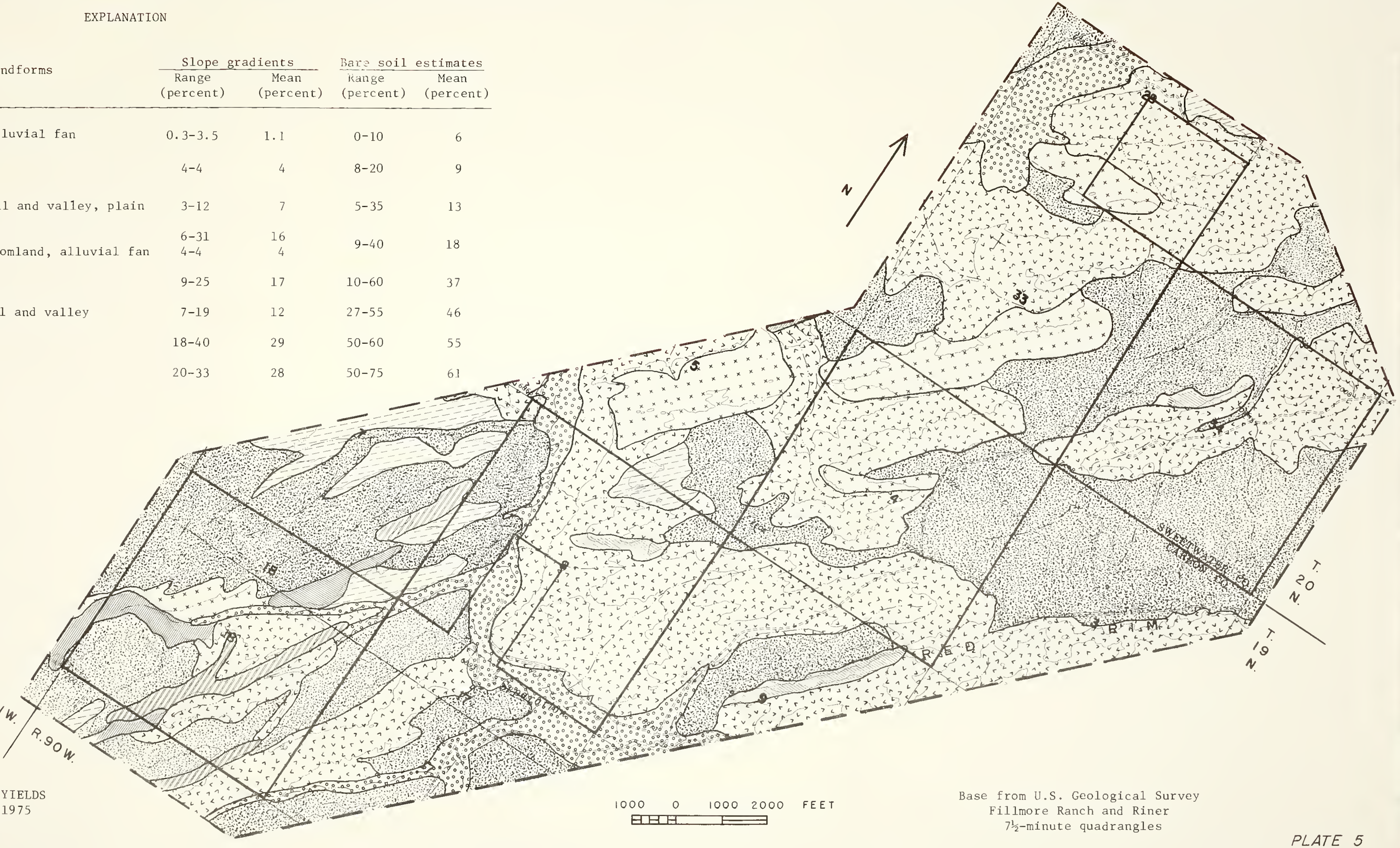
Channel characteristics were measured at selected locations on the study area to obtain indexes of streamflow characteristics and

EXPLANATION

Estimated annual source-area sediment yields (acre-ft/mi^2)	Landforms	Slope gradients Range (percent)	Slope gradients Mean (percent)	Bare soil estimates Range (percent)	Bare soil estimates Mean (percent)
0-.05	bottomland, alluvial fan	0.3-3.5	1.1	0-10	6
.05-.15	bottomland	4-4	4	8-20	9
Low					
.15-.3	hillslope, hill and valley, plain	3-12	7	5-35	13
.3-.5	hillslope dissected bottomland, alluvial fan	6-31 4-4	16 4	9-40	18
Moderate					
.5-.7	hillslope	9-25	17	10-60	37
.7-.9	hillslope, hill and valley	7-19	12	27-55	46
.9-1.2	hillslope	18-40	29	50-60	55
High					
1.2-1.6	hillslope	20-33	28	50-75	61

Study area boundary

Boundary of mapped area



ESTIMATED ANNUAL SOURCE-AREA SEDIMENT YIELDS
FOR THE RED RIM STUDY AREA--WYOMING, 1975

1000 0 1000 2000 FEET

Base from U.S. Geological Survey
Fillmore Ranch and Riner
7½-minute quadrangles

PLATE 5

sediment transport capabilities, and samples were taken with which to determine particle-size distribution of the bed and bank materials (table 15). The complete main channel system was classified according to channel type and condition (plate 6). The channel classification was done by interpretation of the 1:12,000 scale aerial photography, and only those channels that were larger than about fourth order according to Strahler's (1952) classification were delineated. These analyses of the channel system will serve as baseline information and they should be useful in preparing the design criteria for reshaping the terrain if the area is mined. The channel-classification information was also used in deriving the sediment-conveyance factor as the different sediment-transport efficiencies and sediment-deposition attributes associated with those efficiencies. The scheme used in assigning the sediment-conveyance factor was used previously by Frickel, Shown, and Patton (1975). The scheme considers the effects on sediment transport of various conditions such as (1) channel width and gradient, (2) whether the channel is gullied or not, (3) size of the bed material, and type and density of vegetative cover on the channel bed, (4) intermittent gullies in the channel system, (5) evidence of deposition in the channels and the occurrence of alluvial fans, and (6) deposition on bottomlands where flows spread either naturally or because of manmade impoundments or diversions of water.

Source-area sediment yields

Source-area sediment yields on the Red Rim Study Area, while rather variable, are generally low to moderate as shown on plate 5. This is attributed to the soils being generally permeable, resulting in low rates of overland flow. Much of the variation in source-area sediment yields can be attributed to difference in slope steepness and differences in amount of bare soil as indicated in the explanation on plate 5. These two factors are probably not the only ones controlling sediment yields, but bare soil, especially, is an integrating factor that accounts for soil type, amount of runoff or run-in water, slope orientation, and type and intensity of land use. There is appreciable range in values for bare soil and slope within each source-area sediment-yield class shown on plate 5, but the mean values of both correlate very well with the midpoint values of source-area sediment yields. The relationship of source-area sediment yield to mean percent bare soil had a correlation coefficient of 0.98 and a standard error of estimate of 0.1 acre-feet per square mile. The relationship of percent slope to source-area sediment yields had a correlation coefficient of 0.91 and a standard error of estimate of 0.2 acre-feet per square mile.

Table 15 --Channel characteristics at selected locations on the Red Rim Study Area

Channel section 1/	Drainage area (mi^2)	Active channel geometry			Median grain size (mm)		Other characteristics
		width (ft)	depth (ft)	gradient (percent)	Bed material	Bank material	
A	0.35	6.8	0.78	1.0	Silty clay	Silty clay	U-shaped gully with sparse grass on bed; moderate sediment transport.
B	.90	3.0	.20	2.0			Poor sediment transport.
C	.39	2.3	.17	1.0	.39	.27	Sagebrush and rabbitbrush above active channel level; in some places western wheatgrass growing on bed.
D	35.8	8.5	1.81	2.0	.42	<.06	
E	.39	3.0	.22		.33	.17	
F	.04	2.2	.63	6.0	.30	.21	Incised channel; moderate to high sediment transport.
G	.15	1.8	.20	4.0	.25	.25	Braiding and alluvial fans in the drainageway; poor sediment transport.
H	.06	1.7	.21	2.5	.23	.23	Just a rill in a swale.
I	.37	3.0	.50	.5	.29	<.06	Channel is at bottom of steep — walled gully 20 to 25 ft deep.

1/ Locations of channel sections are shown on plate

Estimated Annual Sediment Discharges from Drainage Basins

Basin	Drainage area (mi^2)	Raw gully density (mi/mi^2)	Weighted source-area sediment yield (acre-ft/mi^2)	Sediment conveyance factor	Basin sediment discharge (acre-ft/mi^2)
A	0.35	0	.14-0.28	.5	.07-.14
B	.90	.12	.19- .35	.4	.08-.14
C	.39	.78	.25- .43	.3	.07-.13
E	.39	2.73	.29- .49	.3	.09-.15
F	.04	6.45	.75-1.05	.5	.38-.53
G	.15	.57	.19- .34	.4	.08-.14
H	.06	0	.15- .30	.6	.09-.18
I	.37	.35	.3 - .5	.4	.12-.20

EXPLANATION

Channel classification	Total length (mi)	Drainage density (mi/mi^2)	Percent of total channel length
Raw gullies	9.33	0.933	18.5
Healed gullies	21.15	2.115	41.8
Untrenched	16.35	1.635	32.3
Aggrading and braided	3.75	.375	7.4
TOTAL	50.58	5.058	100.0

HCD High channel density; usually an area with many rills or small gullies.

Fan

Headcut

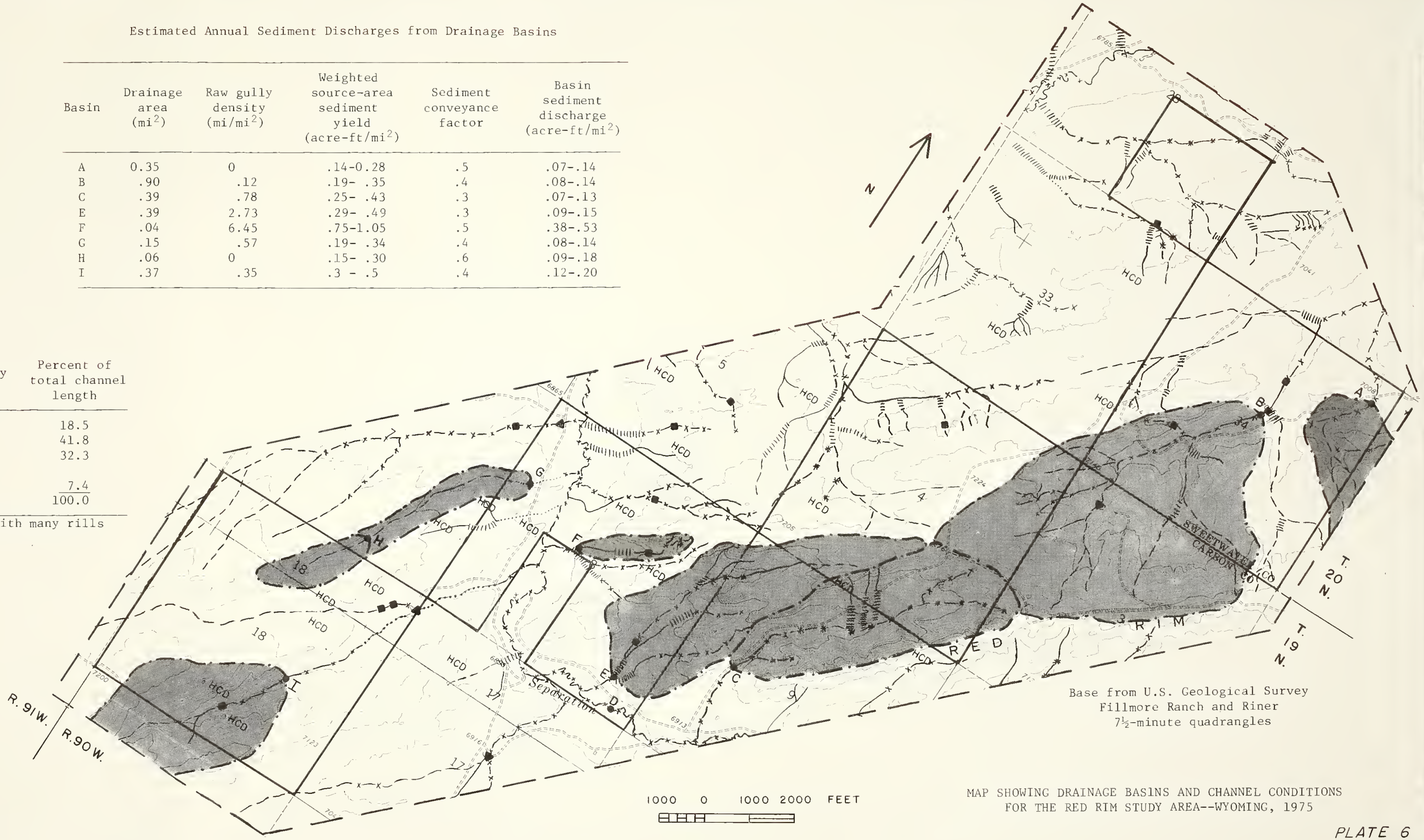
Dam

A Outlets of drainage basins for which sediment yield estimates were made and locations where channel measurements were made.

Drainage divides.

Boundary of study area.

Boundary of mapped area.



Base from U.S. Geological Survey Fillmore Ranch and Riner 7½-minute quadrangles

MAP SHOWING DRAINAGE BASINS AND CHANNEL CONDITIONS FOR THE RED RIM STUDY AREA--WYOMING, 1975

PLATE 6

Channel erosion is judged to be a relatively minor problem on the study area as only 18.5 percent of the primary channel system consists of raw gullies with unvegetated beds (see plate 6). The banks of most of these gullies are stable and, therefore, contribute very little sediment. Several of the headcuts on the site were inspected and indications were that rates of headward advance were less than 10 feet per year. Nearly 80 percent of the primary channel system consists of healed gullies, untrenched channels, and aggrading or braided channels, all of which are channel conditions in which sediment deposition can occur to one extent or another. In addition there are numerous active alluvial fans (see plate 6) on the mapped area where sediment is being deposited. Because of the sediment deposition the channel conveyance factors are significantly less than 1.0 (see table on plate 6) and will remain that way until sometime in the future when the geomorphic cycle is shifted from its present depositional phase to an erosional phase in which much of the sediment presently being deposited will be eroded. The change in phase could be triggered either naturally, such as by climatic shift, or could be caused by man, such as by overgrazing or changes in land use.

Basin-sediment discharges

The estimated sediment-discharge rates from small basins on and near the site are relatively low, as indicated in the table on plate 6 . This is largely attributed to low source-area sediment yields and to dominance of the depositional phase of the geomorphic cycle, with respect to what is happening both in channels and on the slopes.

Low sediment-discharge rates are also indicated by the small amounts of sediment that have been deposited in most of the stock water ponds on and near the study area. Sediment accumulation was measured in two of the ponds as is indicated in table 16 . The accumulation rates in those ponds are lower than the sediment discharges estimated for other small basins in the study area shown in the upper table on plate 6 . One reason for this is that the ponds where the sediment was measured have larger drainage areas above them than the drainage areas are for the basins where sediment discharges were estimated. In semiarid areas such as this it is normal for sediment discharge per unit area to decrease as drainage area increases because of lack of complete coverage by convective storms and because of the increasing number of places where conditions are favorable for sediment deposition. Also, sediment discharge to the pond in section 17 (table 16) is lower because the soils in that basin are sandier than they are on the other basins.

Table 16.--Sediment accumulation measured in two stock water ponds in the Red Rim area

Location	Drainage area (mi^2)	Sediment volume (acre-ft)	Sediment[1] accumulation (acre-ft/mi^2/yr)
T. 19 N., R. 90 W., SE¼ 17	4.02	1.17	.02
T. 19 N., R. 90 W., NE¼ 18	1.07	.82	.04

[1]Age of these ponds was unavailable. Based on the growth rings of sagebrush growing on the dams, they are at least 17-years old, which was the age used in computing the values shown.

There are a number of the source areas on the study area, particularly those with steep slopes and high sediment yields, that only yield a small part of their sediment to the main channel system. Much of the sediment derived from them is deposited on neighboring, downslope source areas, which are less steep and where well-defined channels end. Only a small part of that sediment is eroded from the latter source area and transported downstream by the main channel system. The 0.9 to 1.2 and the 0.3 to 0.5 acre-feet per square mile source areas going diagonal across to the right of the center of sec. 18, T. 20 N., R. 90 W. are an excellent example of the occurrence of this process (see plate 5). The data shown in the explanation of plate indicate that sediment discharges from basins increase as the density of raw gullies increase. Raw gully density is usually a direct index of sediment-transport efficiency and a inverse index of the amount of deposition occurring in a basin.

Effects of mining

Without reference to a mining plan for an area it is difficult to assess the effects of mining on sediment yield. Nonetheless, if the area is mined, an elaborate system probably will be needed to control erosion and minimize the increasing of sediment loads downstream from the area. The reasons that an elaborate system is needed are that the slopes of much of the area are moderately steep (see explanation table of plate 5) and many of the soils of the area are poorly cohesive and thus easily eroded when not well protected by vegetative cover.

Close-spaced contour furrowing (Branson, Miller, and McQueen, 1966) or gouger pitting (Sindelar, et al., 1974) would reduce erosion and foster establishment of vegetation on areas that are steeper than about 10 percent regardless of the soil type and on all areas topped with fine-textured material regardless of slope.

A drainage network should be constructed when the overburden is reshaped. The valleys should be sufficiently wide so that flows will be shallow and thus less erosive. During mining there likely will be a need for some temporary detention reservoirs to trap sediment from the outer slopes of the spoils areas and from some of the larger haul roads which could generate significant runoff during large storms.

Prolonged discharges of water to tributaries of Seperation Creek from detention reservoirs or from dewatering of mine pits are likely to cause an increase in channel erosion by gully widening and headcutting in untrenched channels. The reason for this is that the normally dry alluvium becomes less cohesive when saturated by prolonged flows and thus more erodible when natural flows occur.

Hydrologic Classification of Land Types Using Rainfall Simulation

Two predominant land types that comprise most of the surface were identified within the Red Rim study area. These were designated hydrologic classes A and B and simulation runs were made on each class in early June 1976 to determine their hydrologic characteristics. These baseline data will be the basis for comparison with future changes which might result from surface mining. Several other land types occur within the study area. These were lumped together and designated hydrologic class C. Due to the limited areal extent of class C, no simulation runs were made.

The extent of each land type was determined from aerial photographs and is shown on plate 7 . Locations where simulation runs were made were designated 4 and 5 and are also shown on plate . Responses similar to that obtained from the applied rainfall could be expected from areas of the same hydrologic class as shown on plate 7 . The simulation sites were chosen to be representative of the soil, vegetation and relief within each hydrologic class. Data obtained at the sites are shown in table 17 and photographs of the sites are shown in figure 16 .

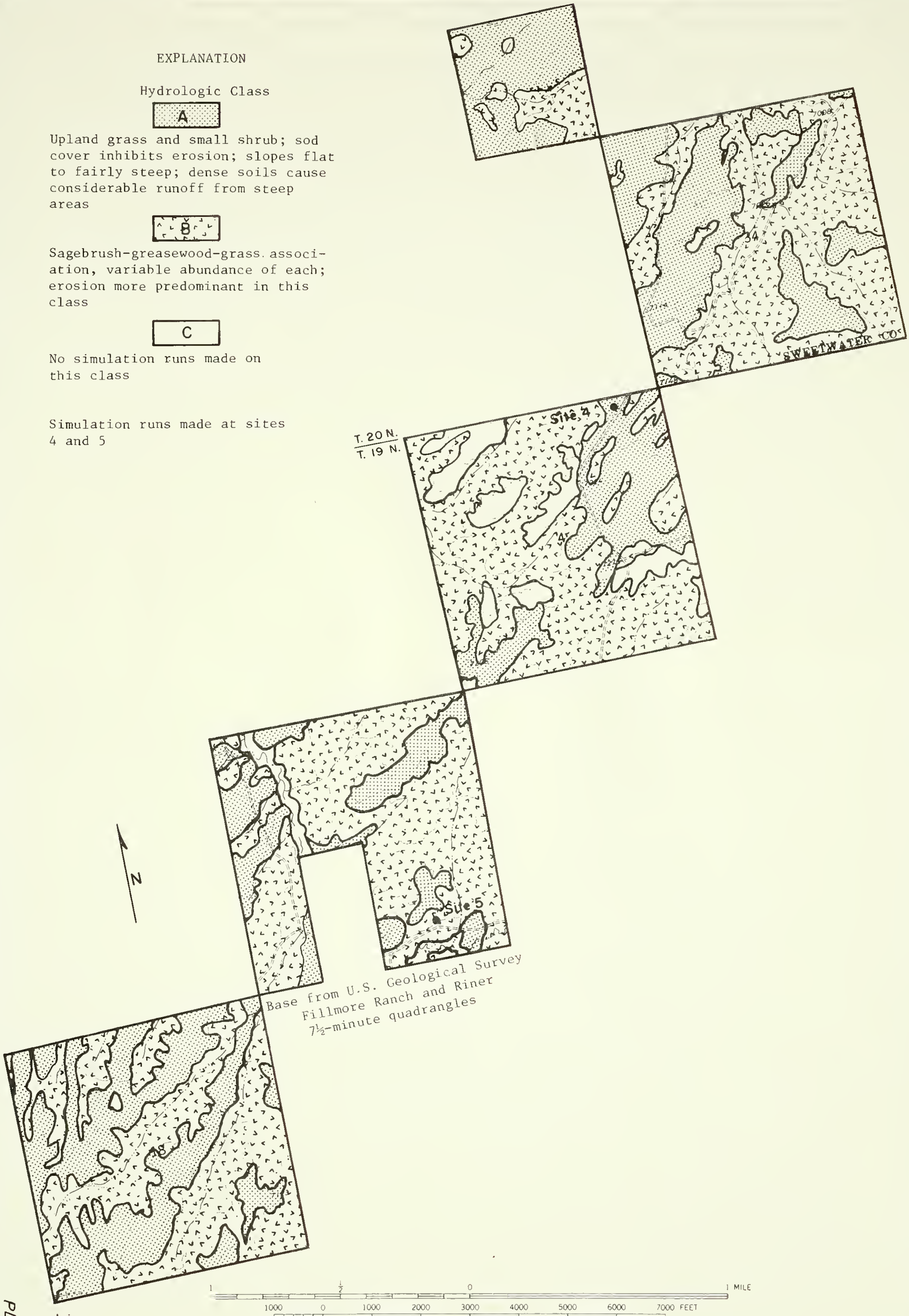
Methods used to obtain the data from each simulation site listed in table 17 are as follows:

1. Runoff--Measured in a Parshall flume with 1-inch throat. Readings of stage made at 1-minute intervals and converted to discharge in cubic feet per second. From these data a runoff hydrograph was constructed and total volume of runoff was computed and expressed in inches per unit area. From these data an infiltration rate curve was also constructed by subtracting the runoff from the rainfall applied for each 1-minute interval and expressed as the infiltration rate in inches per hour.

2. Precipitation--Measured in a network of rain gages within the study area. Rainfall for the total area was computed using the Thiessen Polygon method.

3. Sediment yield--Water samples were obtained from the outflow at 3-minute intervals and were analyzed for sediment concentration. The sediment concentrations were plotted and a concentration curve was drawn between points. From this curve a concentration was obtained for each minute to compute the sediment load. Total sediment load is expressed in pounds and in tons per square mile.

4. Area--Obtained from a topographic survey of the site. Expressed in square feet.



HYDROLOGIC CLASSIFICATION OF THE RED RIM, WYOMING EMRIA STUDY AREA

PLATE 7

Figure 16.--Red Rim simulation sites. Upper photograph is site 4 and lower photograph is site 5.

Table 17.--Data obtained from simulation sites at Red Rim study area.

Variable	Site 4 Dry	Site 4 Wet	Site 5 Dry	Site 5 Wet
Date	7-01-76	7-02-76	7-04-76	7-04-76
Area (sq. ft.)	2,835	2,835	2,526	2,526
Weighted mean slope (percent)	7.7	7.7	6.9	6.9
Antecedent moisture (percent)	5.1	12.0	4.7	18.1
Clay (percent)	25.4	25.4	22.6	22.6
Root concentration (g/100 g)	.490	.490	.710	.710
Bare soil and rock (percent)	30.8	30.8	33.0	33.0
Precipitation (inches)	1.42	1.59	1.53	1.42
Runoff (inches)	.09	.54	.32	.78
Sediment yield				
pounds	1.32	10.24	29.17	81.79
tons per sq. mi.	6.5	50.3	161	451
Reconstructed runoff (inches)	.13	.50	.27	.86

5. Weighted mean slope--Obtained by measuring the area between contours and weighting the slope of that area according to the percentage the area is of the whole.

6. Antecedent moisture--Obtained from gravimetric samples of the top 10 centimeters of soil. Samples are usually taken at four locations within the site and averaged for the final result. Expressed as percentage by weight. Two runs are normally made at each site. The first is made in a dry condition and again after water in the soil has come to a gravimetric equilibrium. Soil moisture samples are taken before each run.

7. Clay--Obtained from soil samples taken from the top 10 centimeters of soil at numerous locations within the site. Samples are analyzed for percentage by weight of material less than 0.002 millimeters in diameter.

8. Root concentration--The amount of fibrous root material in the top 10 centimeters of soil. Expressed in grams per 100 grams of soil.

9. Bare soil and rock--Obtained from three 20-foot transects within each site using a point frame and the first contact point method. Pins lowered to the vegetation or ground surface at 2-inch intervals are recorded at first encountering of aerial vegetation, mulch, bare soil or rock. Expressed as hits per 100 pins or percent cover.

10. Reconstructed runoff--Rainfall applied normally varies somewhat about the standard of 1.5 inches in 45 minutes. In order to compare runoff results on a standard basis, a runoff hydrograph is reconstructed by determining the runoff that would result from subtracting the infiltrated water determined during the simulation event from the water applied during a standard storm of 1.5 inches in 45 minutes for each minute increment.

Chemical Analyses

Samples of the outflow from each site were obtained at 3-minute intervals for chemical analyses. These samples were composited in sequential groups so that three or four samples were obtained for the entire runoff period. An analysis was made on each composite sample for the items listed in table 18. An analysis of the water applied is used as a standard, and other values listed are either an increase (+) or decrease (-) of these values in the runoff water.

Table 18.--Changes in water chemistry (+ or -) of runoff water as compared to applied water.

			Variable											
					Cations (mg/L)				Anions (mg/L)					
Site	Composite	pH	Specific Conduct.	Residue mg/L	Calcium	Magnesium	Potassium	Sodium	Bicarb.	Carbonate	Chloride	Flouride	Sulfate	NO_2+NO_3
Red Rim 4-Dry	Applied	8.3	1,080	714	76	69	4.7	75	346	0	13	0.4	300	0.18
	1	- .7	+ 40	+ 30	+13	-5	+ 2.9	- 1	+39	0	-1	-.1	0	+.01
	2	- .7	+ 40	+ 45	+11	-9	+ 2.4	+ 1	+37	0	0	0	+ 20	0
Red Rim 4-Wet	Applied	8.3	1,080	714	76	69	4.7	75	346	0	13	0.4	300	0.18
	1	- .5	+100	+ 60	+13	-2	+ 2.2	+ 2	+27	0	+1	0	+ 30	-.17
	2	- .5	+70	+ 25	+10	-4	+ 1.7	+ 2	+29	0	+1	0	0	-.17
	3	- .4	+70	+ 30	+11	-5	+ 1.6	+ 3	+38	0	+1	0	0	-.17
Red Rim 5-Dry	Applied	8.3	1,080	714	76	69	4.7	75	346	0	13	0.4	300	0.18
	1	-1.0	+350	+254	+44	+3	+13.3	+25	+36	0	+6	-.1	+150	+.38
	2	- .8	+320	+245	+44	+7	+ 8.3	+23	+34	0	+4	-.1	+150	0
	3	- .7	+340	+266	+44	+8	+ 8.3	+25	+32	0	+4	-.1	+170	-.11
Red Rim 5-Wet	Applied	8.3	1,080	714	76	69	4.7	75	346	0	13	0.4	300	0.18
	1	- .7	+460	+306	+44	+8	+10.3	+35	+69	0	+7	-.1	+180	-.09
	2	- .7	+430	+296	+44	+8	+12.3	+45	+30	0	+6	-.1	+170	+.17
	3	- .7	+420	+296	+44	+8	+13.3	+45	+70	0	+6	-.1	+150	+.23

Precipitation

A frequency of recurrence of maximum daily precipitation during the months April through October at Rawlings, Wyoming, is shown on figure 17. Rawlins is the nearest long-term weather station to the study area. From this curve the following data on the magnitude of storms of various recurrence interval were obtained. These data give a general idea of storms at the study area.

Recurrence Interval (years)	Precipitation (inches)
2.33	0.73
10	1.18
25	1.38
50	1.64

Simulation Sites and Hydrologic Classes

A description of each simulation site and of each hydrologic class follows. A list of precipitation events of different recurrence intervals and duration that were obtained from Weather Bureau Technical Paper 40 are also shown for each site. The volume of runoff that might be expected from each of these events was computed using infiltration rates obtained from the dry-condition simulation events.

Hydrologic Class A

This class consists of upland grass and small shrub-type vegetation. Slopes range from almost flat to fairly steep. A relatively good sod cover is present on much of the area and this inhibits erosion, but soils are dense and produce sizeable amounts of runoff, especially on the steeper areas. The following data were obtained from the simulation site, designated site 4.

Weighted mean slope = 7.7 percent
Clay = 25.4 percent
Bare soil and rock = 30.8 percent

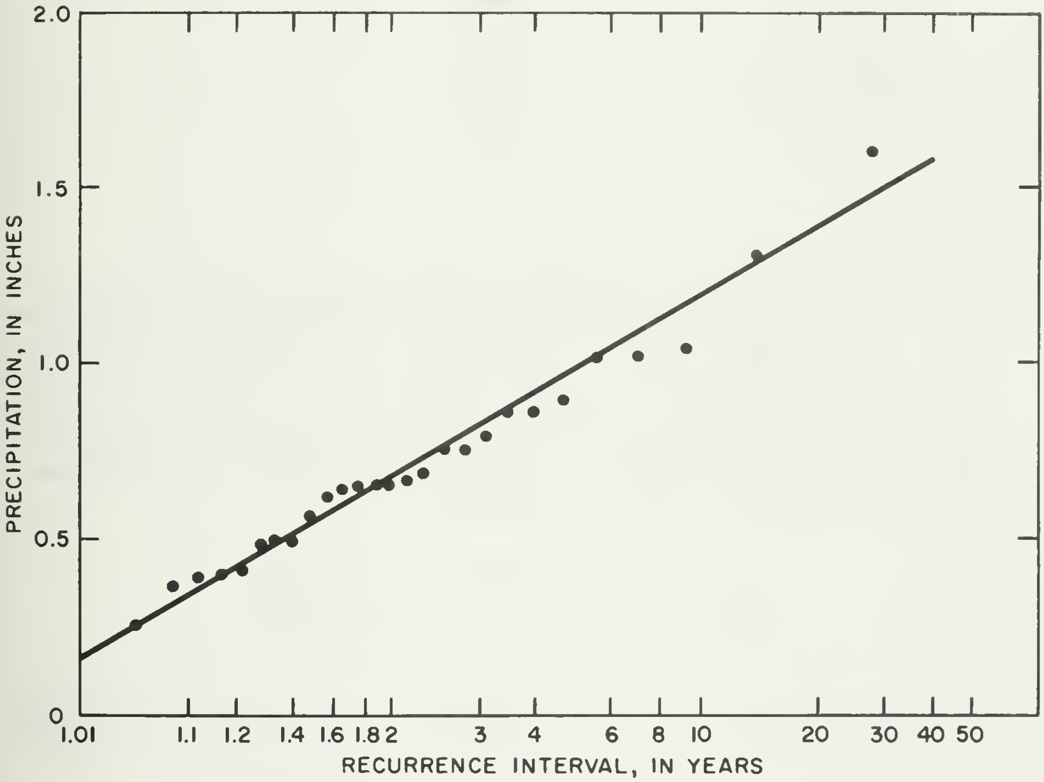


Figure 17 .--Recurrence of maximum yearly 24 hour rainfall (Apr-Oct) at Rawlins, Wyo.

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

RI/D/M	AM = 5.1	AM=12.0
2/30/0.50	0	0
10/30/0.80	0	.12
25/30/1.00	.03	.26
50/30/1.15	.08	.38
2/60/0.55	0	0
10/60/1.00	0	0
25/60/1.25	0	.11
50/60/1.40	0	.22

Hydrologic Class B

This class consists of sagebrush-greasewood-grass association. The relative abundance of each of these species within the stand varies considerably over the study area. In areas where greasewood is abundant, such as at the simulation site, a large increase in dissolved solids in the runoff water can be expected. In most areas a sparse understory of grass tends to make erosion more predominant than in class A. The following data were obtained from the simulation site, designated site 5.

Weighted mean slope = 6.9 percent
Clay = 22.6 percent
Bare soil and rock = 33.0 percent

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

RI/D/M	AM = 4.7	AM = 18.1
2/30/0.50	0	0.09
10/20/0.80	0	.35
25/30/1.00	.11	.54
50/30/1.15	.23	.70
2/60/0.55	0	0
10/60/1.00	0	.28
25/60/1.25	0	.50
50/60/1.40	0	.64

Runoff, Infiltration Rates and Sediment Concentration

The curves for runoff, sediment concentration, and infiltration rates for the simulation sites are shown in figures 18 through 21. The horizontal part of the infiltration curve indicates that the actual infiltration rate exceeded the rainfall rate. Water discharge is in cubic feet per second and sediment concentration in milligrams per liter.

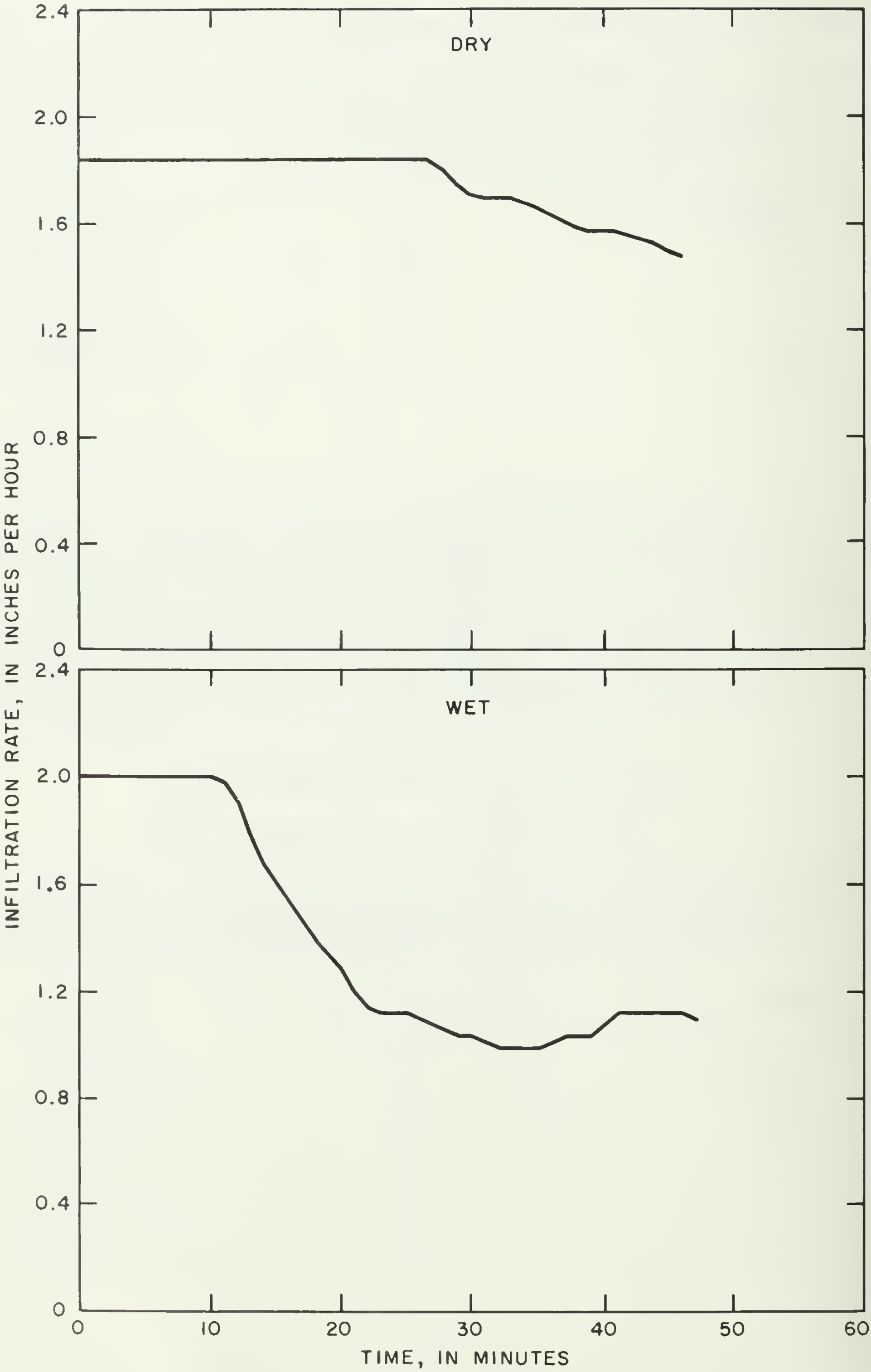


Figure 18.--Infiltration curves for Red Rim site 4.

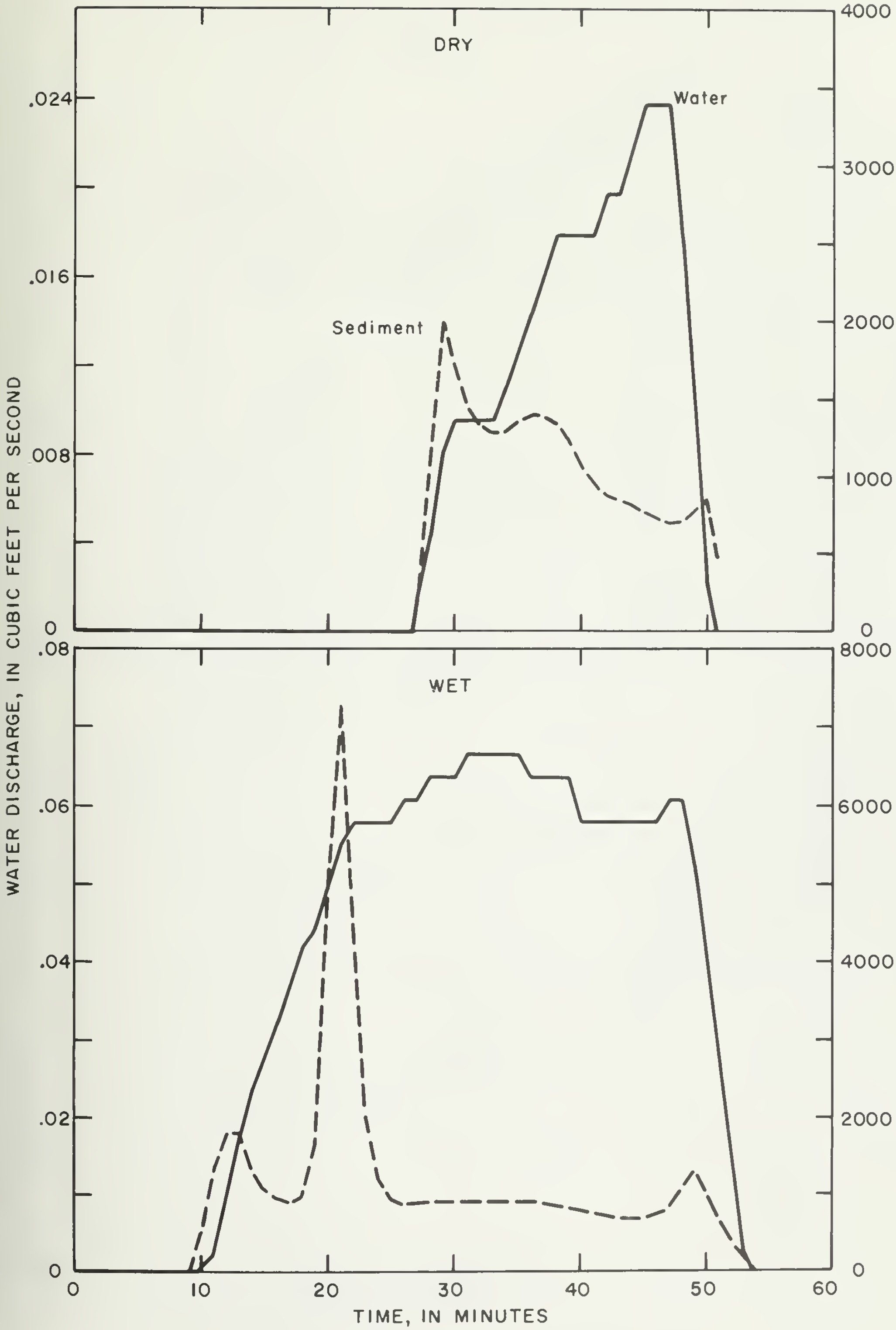


Figure 19.--Hydrographs and sediment concentration curves for Red Rim site 4.

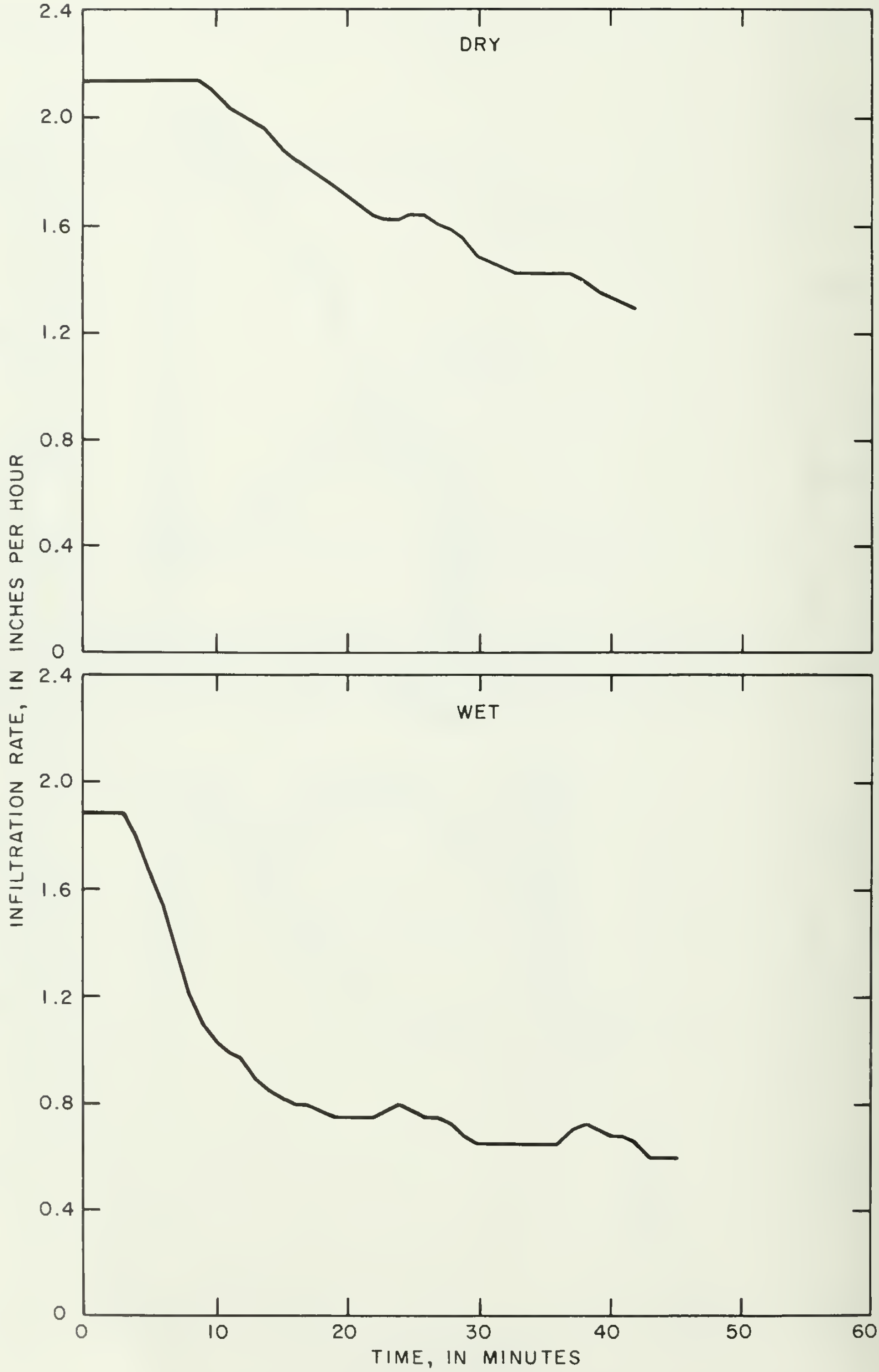


Figure 20.--Infiltration curves for Red Rim site 5.

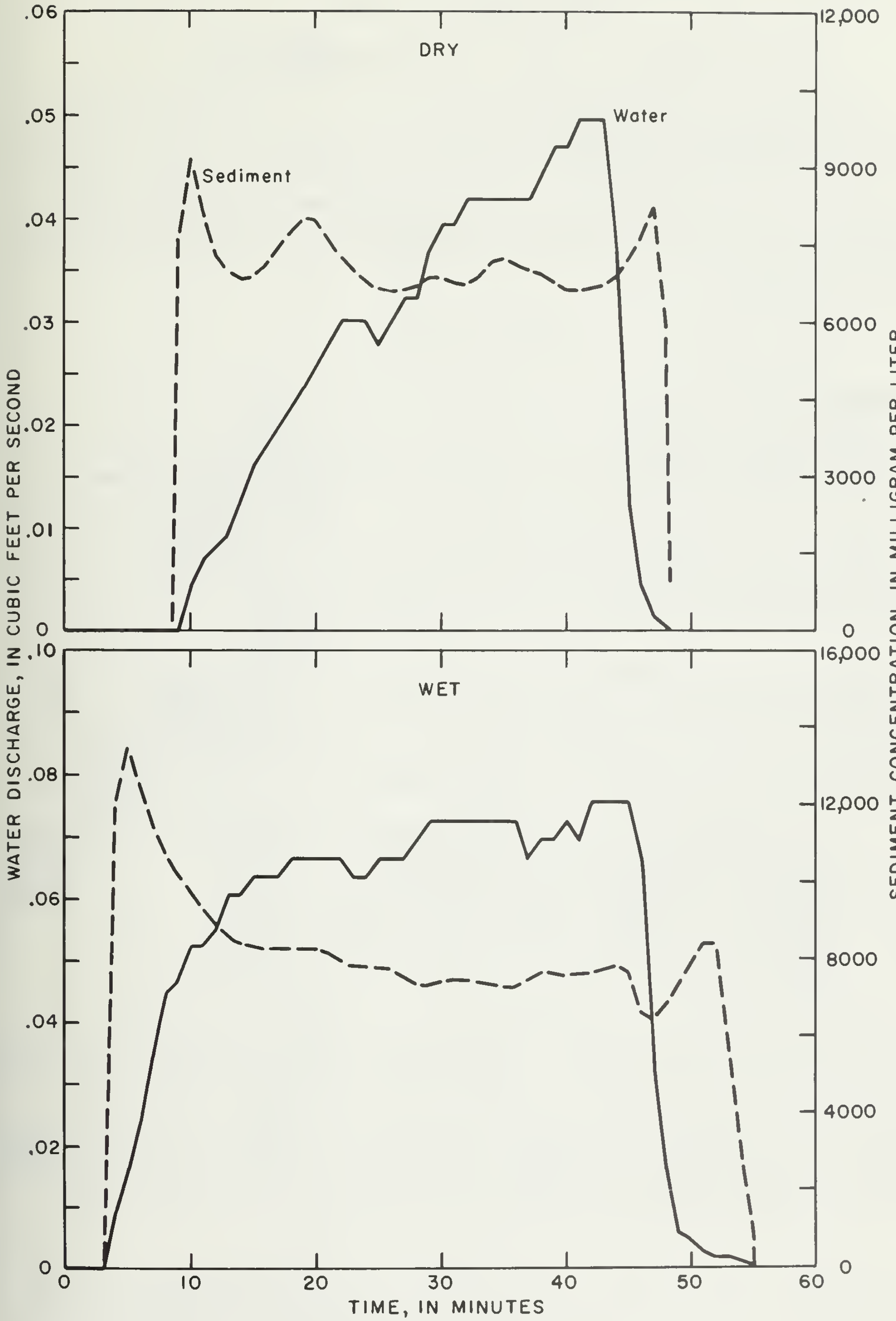


Figure 21.--Hydrographs and sediment concentration curves for Red Rim site 5.

Study Site Hydrology and Water Supply

The study of hydrology of the Red Rim study area was directed toward: 1) Defining important hydrologic variables in and near the study site; 2) determining the relation of hydrology to other aspects of the environment, including erosion and sedimentation, the biologic community, and land use; and 3) determining, with the aid of the above relations, reactions of the environment to various schemes of mining and rehabilitation.

Surface Waters

Streamflow

The Red Rim study area is located in the Great Divide Basin and is drained by Separation Creek and its tributaries. Figure 22 shows the location of the study site with respect to the Separation Creek drainage. Also shown on the figure are the locations of sites where streamflow and water-quality measurements were obtained during 1975 and 1976. Separation Creek has perennial flow upstream from about site S-20 but is intermittent downstream from that site.

Figure 23 is a hydrograph of Separation Creek at streamflow station 09216527 (site S-29) for the 1976 water year. Annual runoff for the 1976 water year was 2,040 acre-feet at the above station. Based on channel and basin features (Lowham, 1976), estimates of long-term flow characteristics at streamflow station 09216527 are:

2-year peak flow = 39 cubic feet per second;
5-year peak flow = 100 cubic feet per second;
10-year peak flow = 170 cubic feet per second;
25-year peak flow = 290 cubic feet per second;
50-year peak flow = 420 cubic feet per second;
Average annual runoff = 1,500 acre-feet per year.

The major part of annual runoff occurs during spring and early summer as a result of snowmelt. The headwaters area upstream from about site 20c contributes the major part of the stream's runoff as greater snowpack occurs at higher elevations, especially above 7,000 feet. Runoff is highly dependent on precipitation, and precipitation is highly variable as is shown by figure 24. Photo 16 is a photograph of Separation Creek at streamflow station 09216527 (site S-29), and photo 17 is a photograph of the headwaters area above site S-6.

The main use of surface waters in and near the study site is for consumption by livestock and wildlife. Several small stockponds have been constructed on Separation Creek to supplement late summer and fall water supplies. Water from Separation Creek is used for irrigation of hay fields near site S-41.

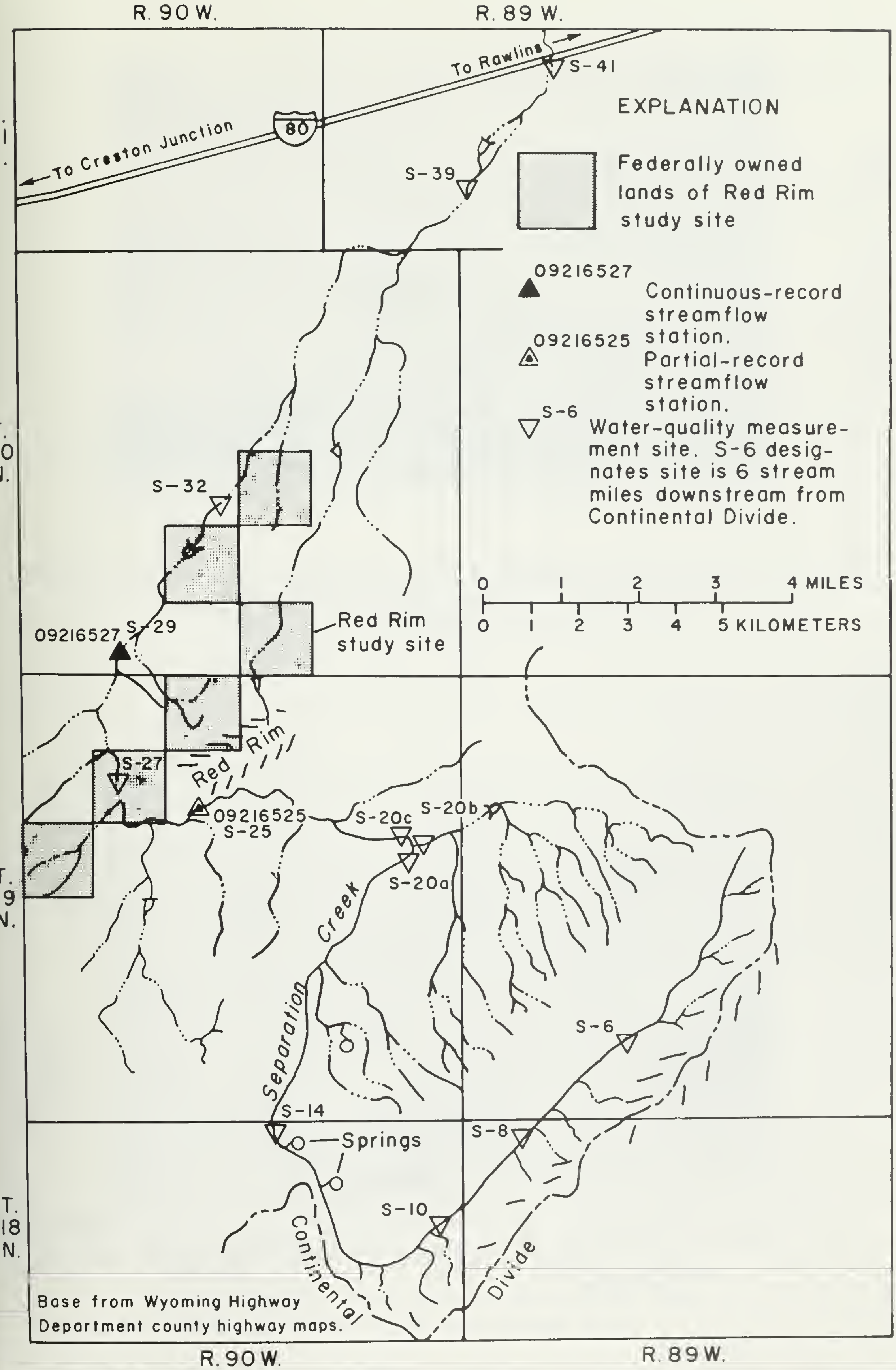


Figure 22.—Location of Red Rim study site in relation to Separation Creek.

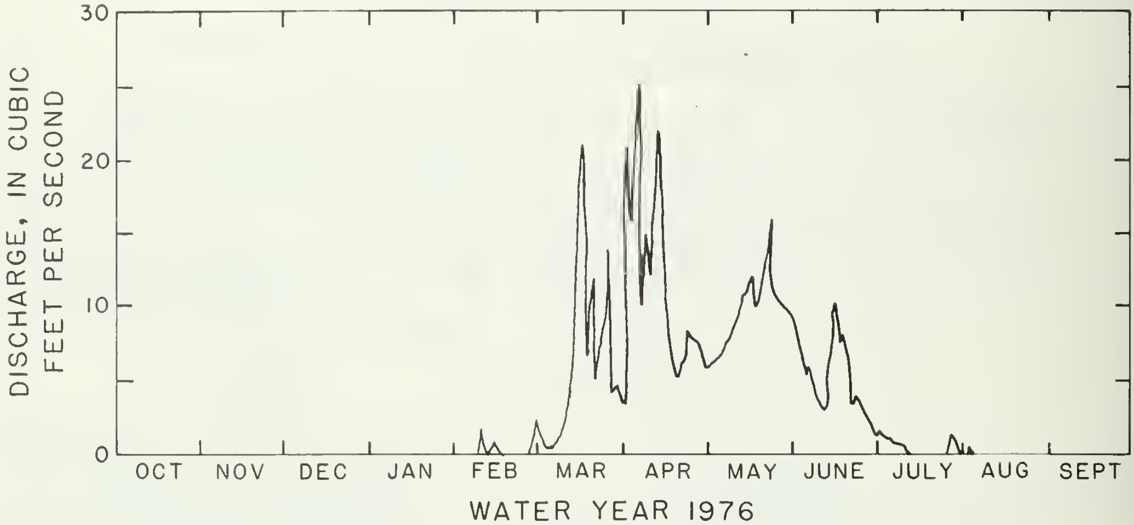


Figure 23 .—Daily discharge at station 09216527, Separation Creek near Riner, Wyoming (1976 water year).

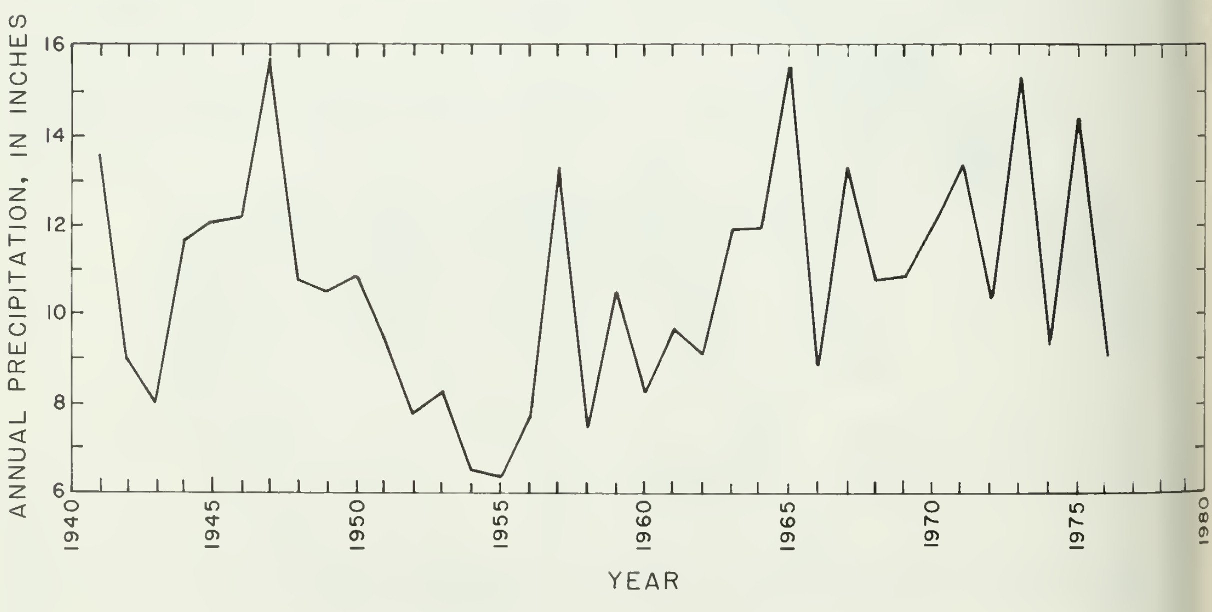


Figure 24 .—Long-term variation in annual precipitation--average of data from Rock Springs FAA AP and Seminoe Dam weather stations.

Separation Creek at streamflow station 09216527 (site S-29). Photograph taken during March 1976. View is looking upstream (south). Note light snow cover.

Photo 16

Separation Creek above site S-6. Photograph taken during March 1976. View is looking upstream (northeast). Note heavier snow cover than shown in photo 16 of downstream site.

Photo 17

Chemical quality

Samples of water from Separation Creek and its tributaries were analyzed for salinity, trace metals, and radiochemicals. Results of the chemical analyses are listed in App.E, tables E1 and E2. A chemical-quality monitor was operated at station 09216527 (site 29) for continuous observation of specific conductance and temperature of flows during the 1976 water year. Figure 25 shows daily discharge, specific conductance, dissolved-solids concentration, and water temperature at the site. The relation of dissolved solids to specific conductance for the stream is shown in figure 26.

Specific conductance (or dissolved-solids concentration) is inversely related to magnitude of discharge as shown in figure 27. The first snowmelt runoff in early spring is low in dissolved solids because the flow is over frozen ground and ice, and has little contact with the soil. As temperatures become warmer, the ground thaws, ice in the channel melts, and the snowmelt comes into contact with weathered and decayed material and salts that have accumulated during the previous fall and winter. After the basin surface and channel have been flushed by these flows, the dissolved-solids concentration of the water decreases as is shown in figure 27.

Areal and temporal variations in the water quality of Separation Creek were observed by sampling at the sites shown on figure 22 during March, May, July, and September. Percent ionic composition and dissolved-solids concentration are shown in figures 28 and 29. Pie diagrams in the figures show there was a general downstream increase in the sodium percentage with an associated decrease in the calcium percentage. For the anions, the sulfate ion increases at the expense of the bicarbonate ion. This change in the percent ionic composition as well as a rapid increase in the dissolved-solids concentration takes place in the reach of Separation Creek upstream from site S-14. Little change in either the type of water or the salt concentration takes place in the reach between sites S-14 and S-25. Figure 30 shows specific conductance, discharge, pH, and dissolved oxygen plotted against stream length for the March, May, July, and September sampling runs.

The trace-metal analyses showed no unusually high concentrations of dissolved trace metals. Total iron and total aluminum are very high (up to 42,000 micrograms per liter iron and 26,000 micrograms per liter aluminum). These high values are caused by the suspended material and have no real significance, other than noting their lack of relationship to the iron and aluminum in the dissolved phase.

Water from Separation Creek is being successfully used for irrigation of native hay near site S-41. The water has a low sodium hazard with a moderate to high salinity hazard. Despite the salinity hazard, it could be used to irrigate during revegetation if salt-tolerant plants were selected and if it were used for only a short period of time.

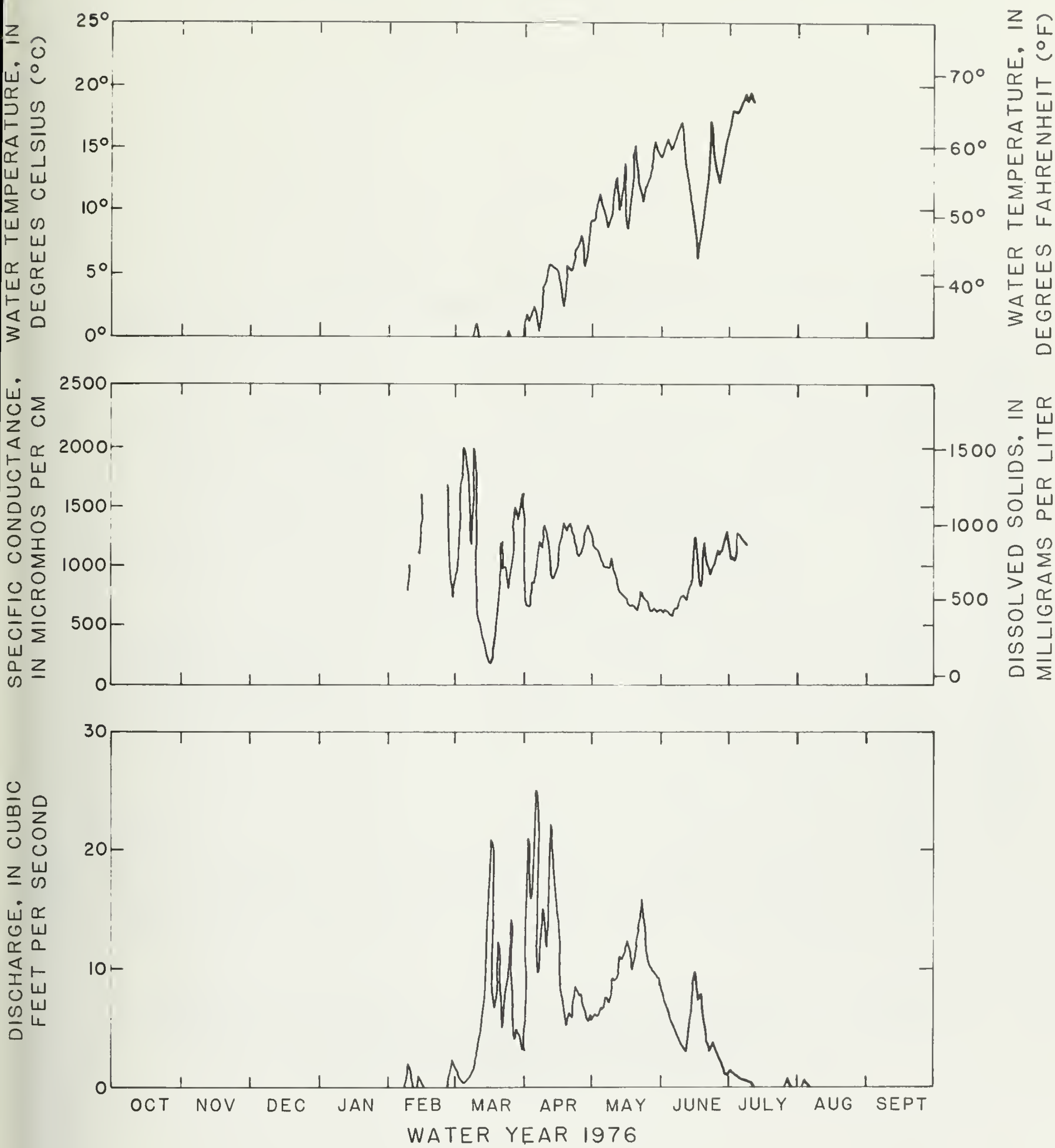


Figure 25 .—Daily discharge, specific conductance, dissolved-solids concentration, and water temperature at streamflow station 09216527 Separation Creek near Riner, Wyoming (1976 water year).

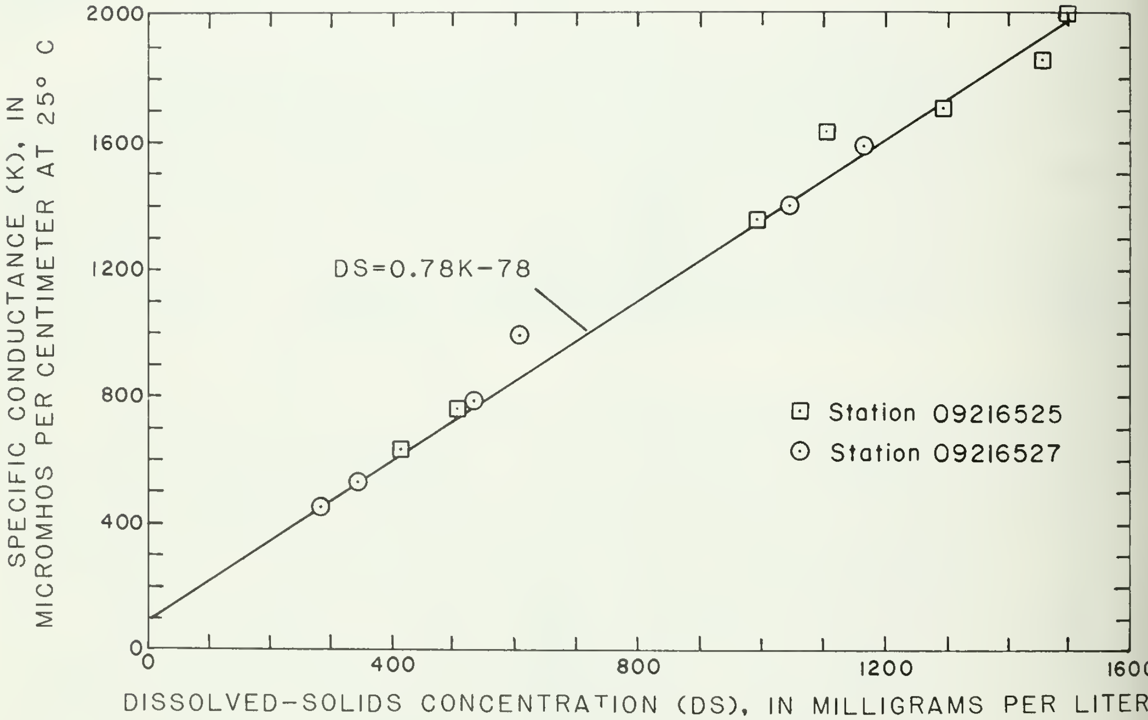


Figure 26.—Relation of dissolved-solids concentration to specific conductance for Separation Creek at stations 09216525 and 09216527.

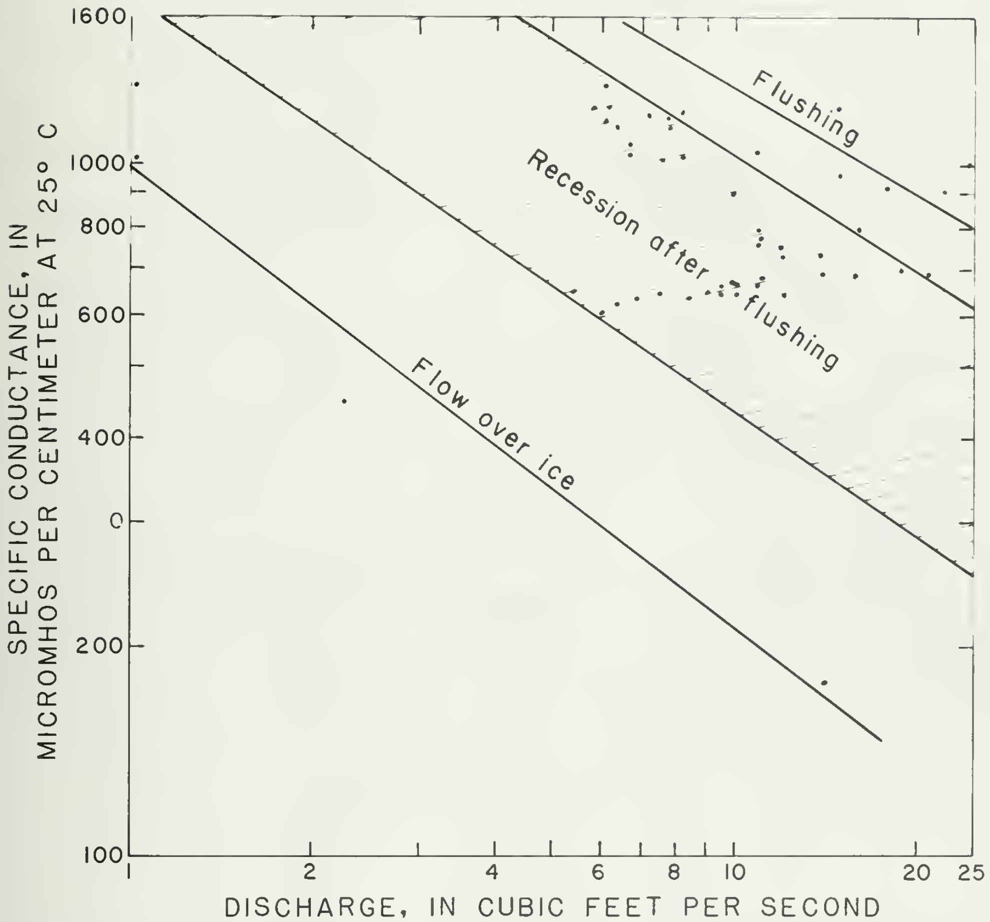


Figure 27 .—Relation of specific conductance to discharge for Separation Creek at station 09216527.

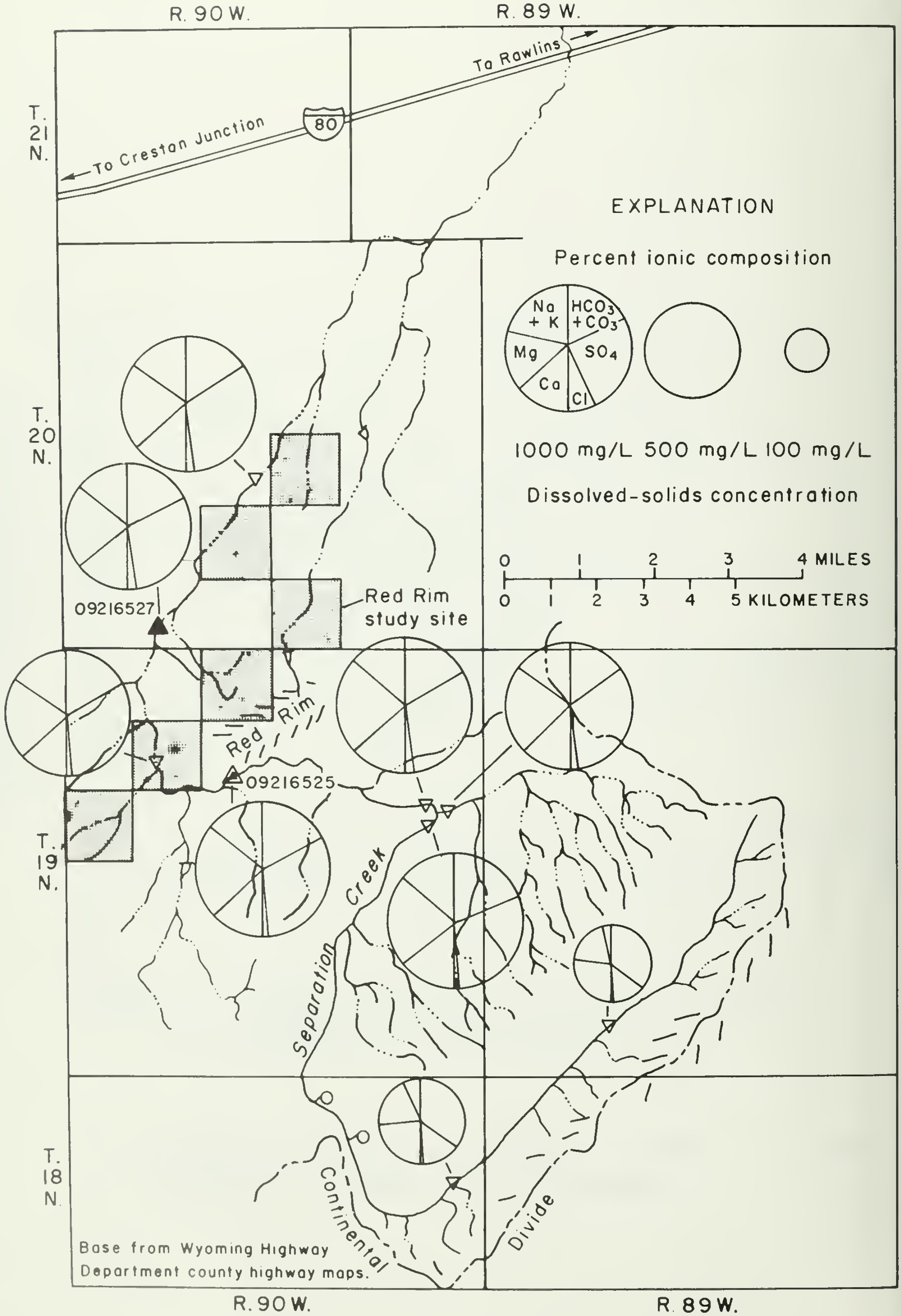


Figure 28.—Ionic composition and dissolved-solids concentration for Separation Creek on March 29, 1976.

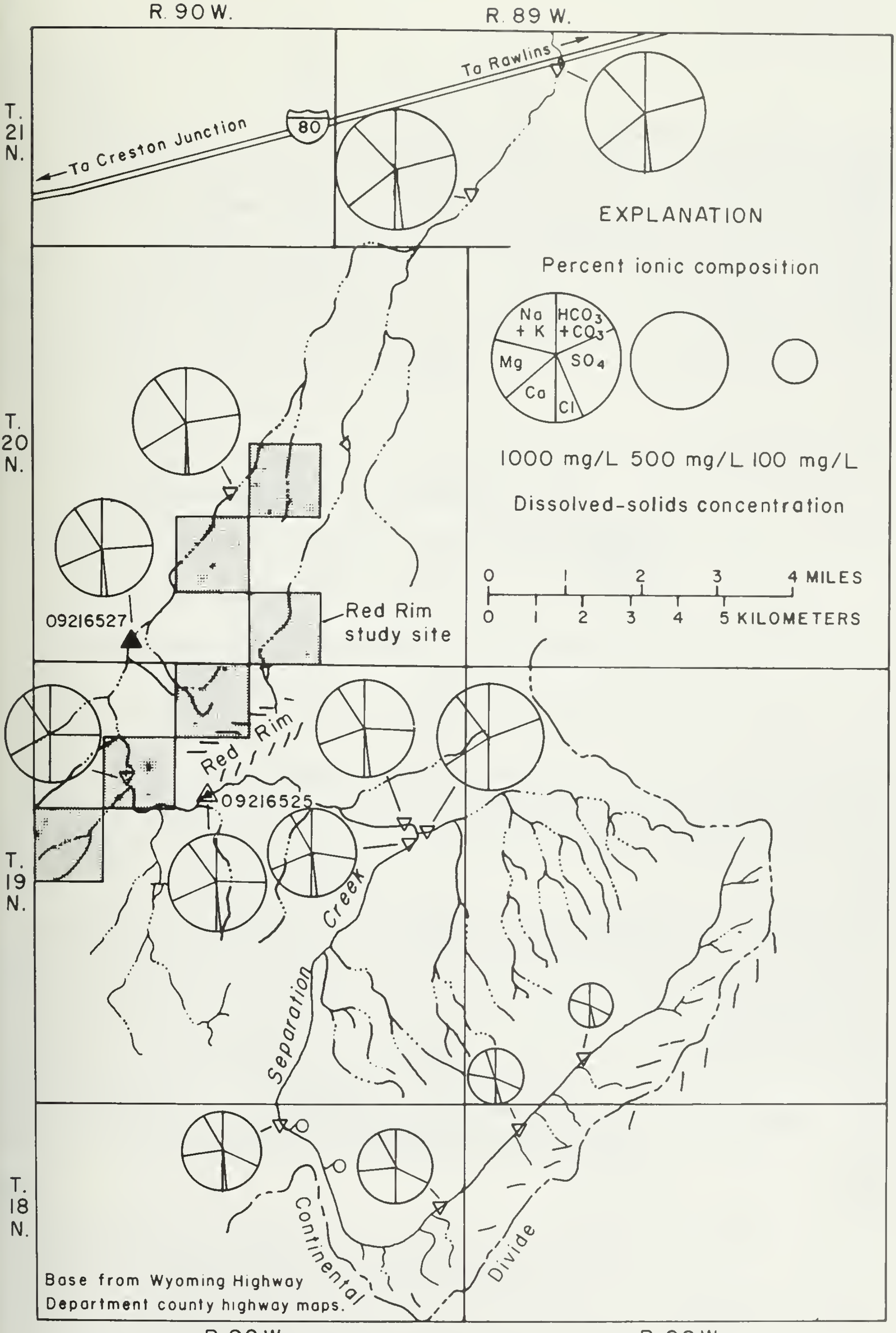


Figure 29.—Ionic composition and dissolved-solids concentration for Separation Creek on May 12 and 13, 1976.

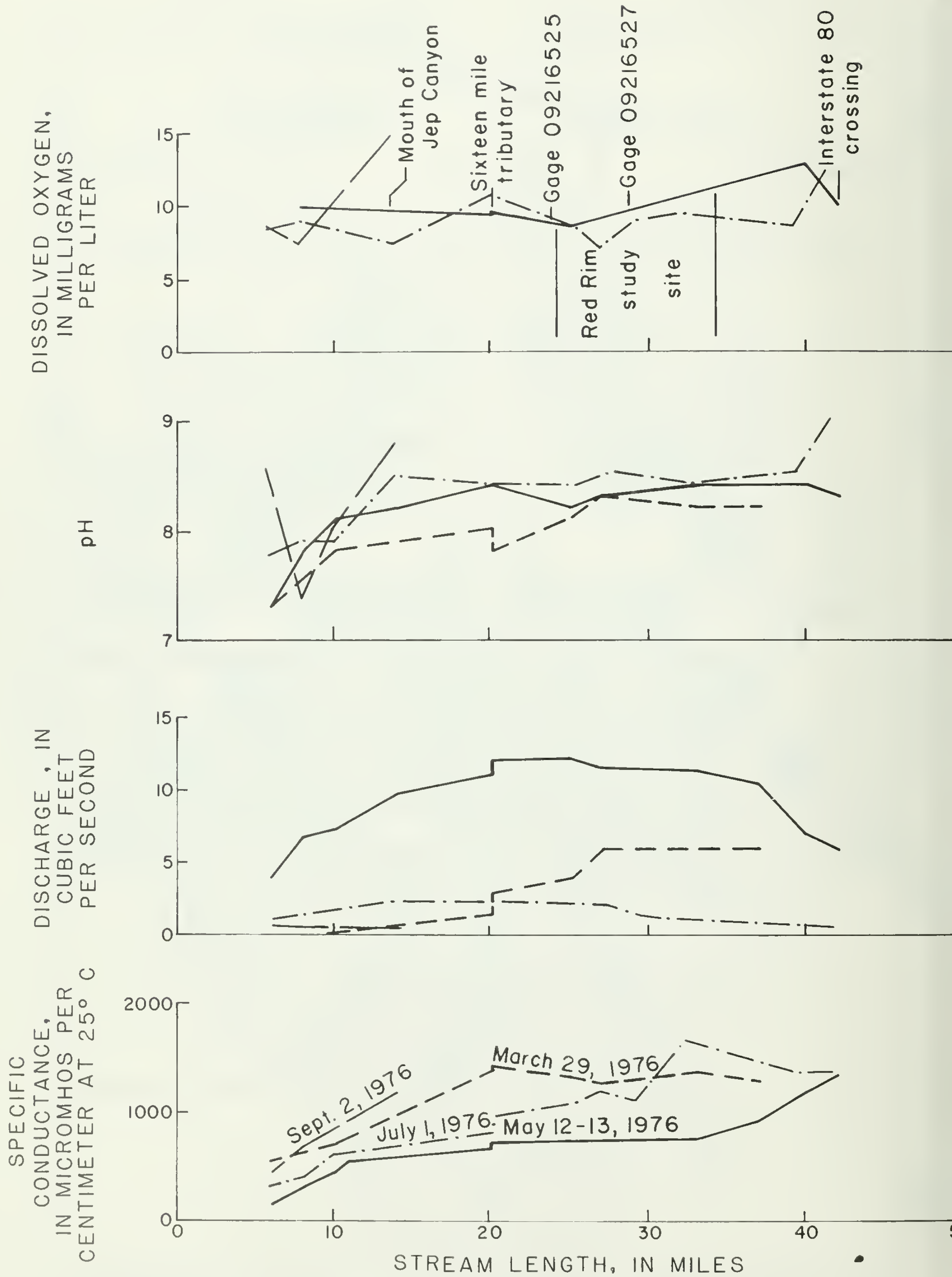


Figure 30.—Measurements of specific conductance, discharge, pH, and dissolved oxygen versus stream length for Separation Creek, Wyoming.

Temperature

The physical, chemical, and biological properties of water are closely related to temperature as it affects sediment transport, rates of chemical reactions, and biological processes. Figure 25 shows observations of daily mean water temperatures for the 1976 water year at station 09216527 (site S-29). A regional analysis of stream-temperature characteristics was made for streams in the Green River and Great Divide Basins using a harmonic curve-fitting procedure (H. W. Lowham, written commun., 1976). It has been shown (Ward, J. C., 1963; and Steele, T. D., 1974) that the following harmonic equation closely fits the annual variation of water temperature at a given site in a stream:

$$T\ (t) = A[\sin(0.0172t + C)] + M$$

where $T\ (t)$ = stream temperature in degrees Celsius on day t of the water year (October 1 is $t = 1$),

A = amplitude of the harmonic, in degrees Celsius,

t = number of days since October 1,

C = phase angle of the harmonic, in radians,

M = mean of the harmonic, in degrees Celsius.

Figure 31 shows a harmonic model of mean daily water temperatures for Separation Creek in the vicinity of the Red Rim study site. The graph shows a comparison of observed daily mean water temperatures at station 09216527 (site S-29) with the expected water temperature as predicted by the harmonic model.

Except for short distances downstream from significant ground-water inflow, water temperature is closely related to surrounding meteorologic conditions. These conditions change with elevation; thus, water temperature does likewise. Figure 32 shows the relation of the harmonic mean of annual water temperature versus elevation for streams in the Green River and Great Divide Basins of Wyoming. The relation shows that the decrease in elevation of Separation Creek from 8,445 feet at the Continental Divide to 6,395 feet at Separation Lake would be accompanied by an increase in mean water temperature in the downstream direction.

Sediment

Sediment is an important factor of water quality in the study area. Sediment concentration can affect the use of water and design of structures. Sediment also affects turbidity, which is important to aesthetic value and certain biological relations. App. E table E3 lists results of sediment and turbidity data gathered during the study period. Figure 33 shows daily discharge, suspended-sediment concentration, and suspended-sediment load at streamflow station 09216527 Separation Creek near Riner, Wyoming for the 1976 water year.

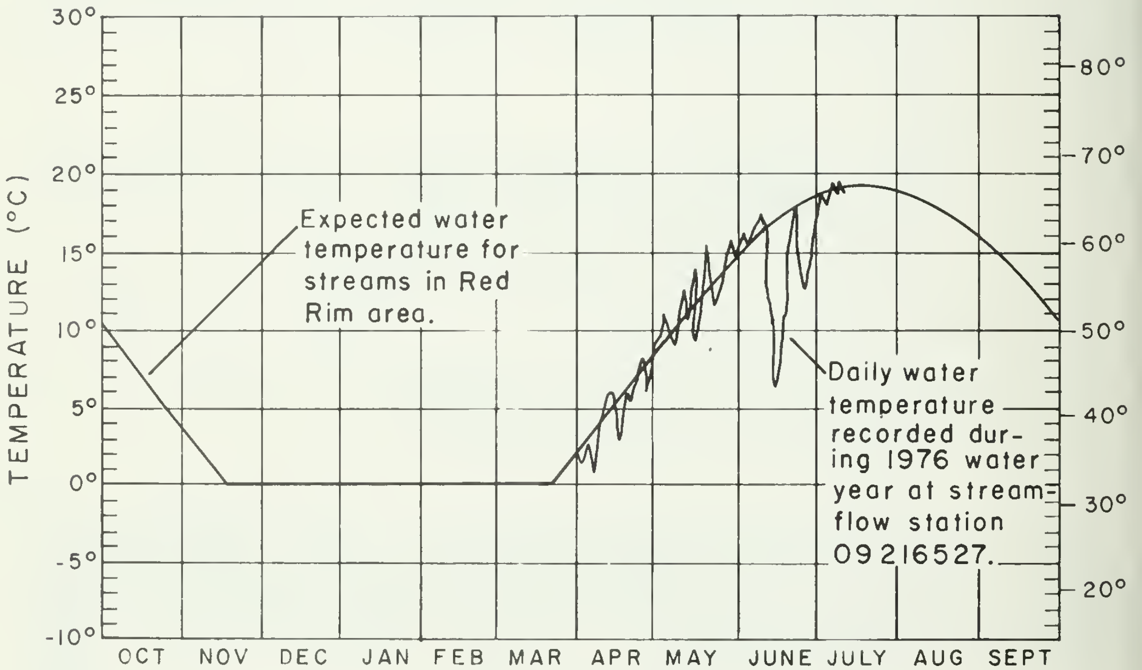


Figure 31 .—Harmonic model of water temperature for Separation Creek in the vicinity of the Red Rim study site.

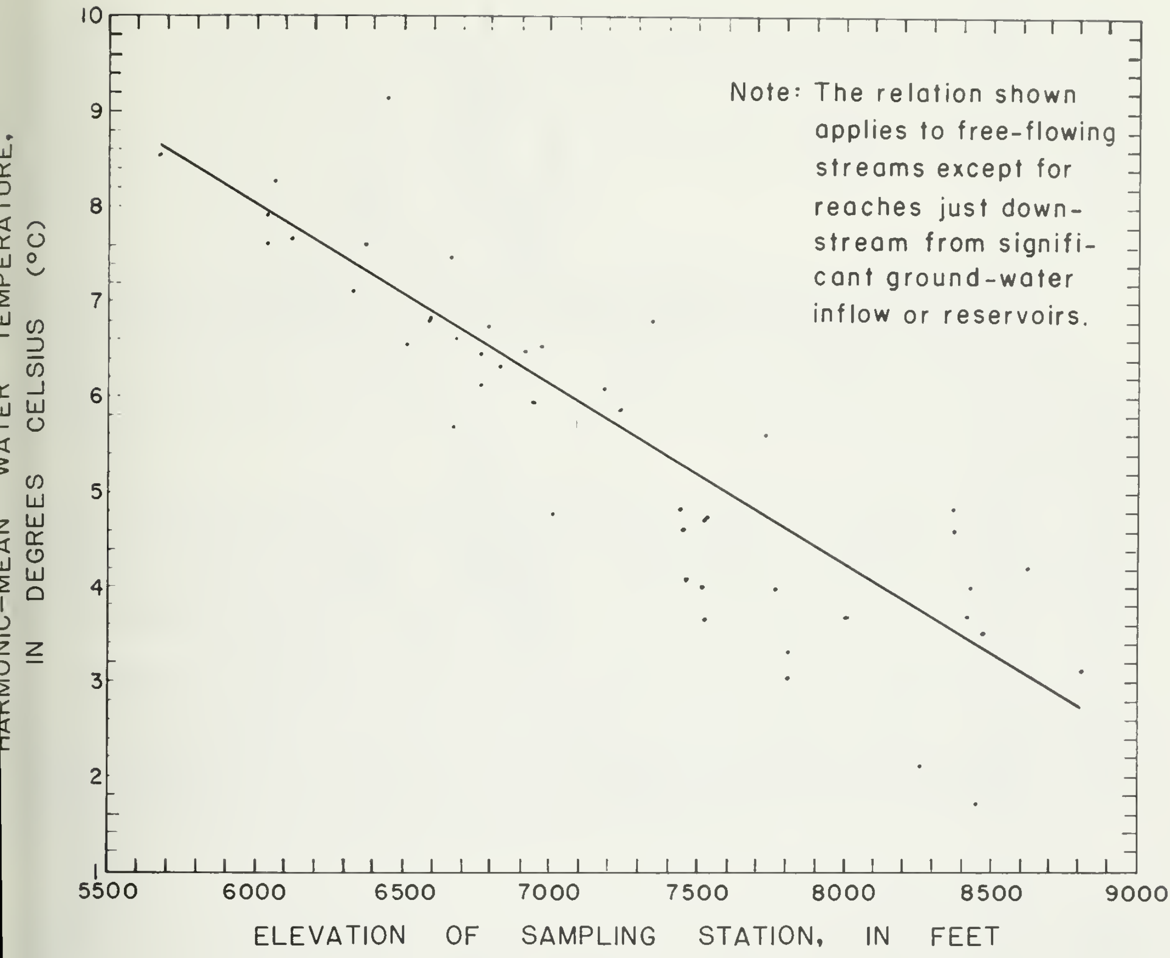


Figure 32 .—Relation of harmonic mean of annual water temperature versus elevation of sampling station for streams in the Green River and Great Divide Basins of Wyoming (H. W. Lowham, written commun., 1976).

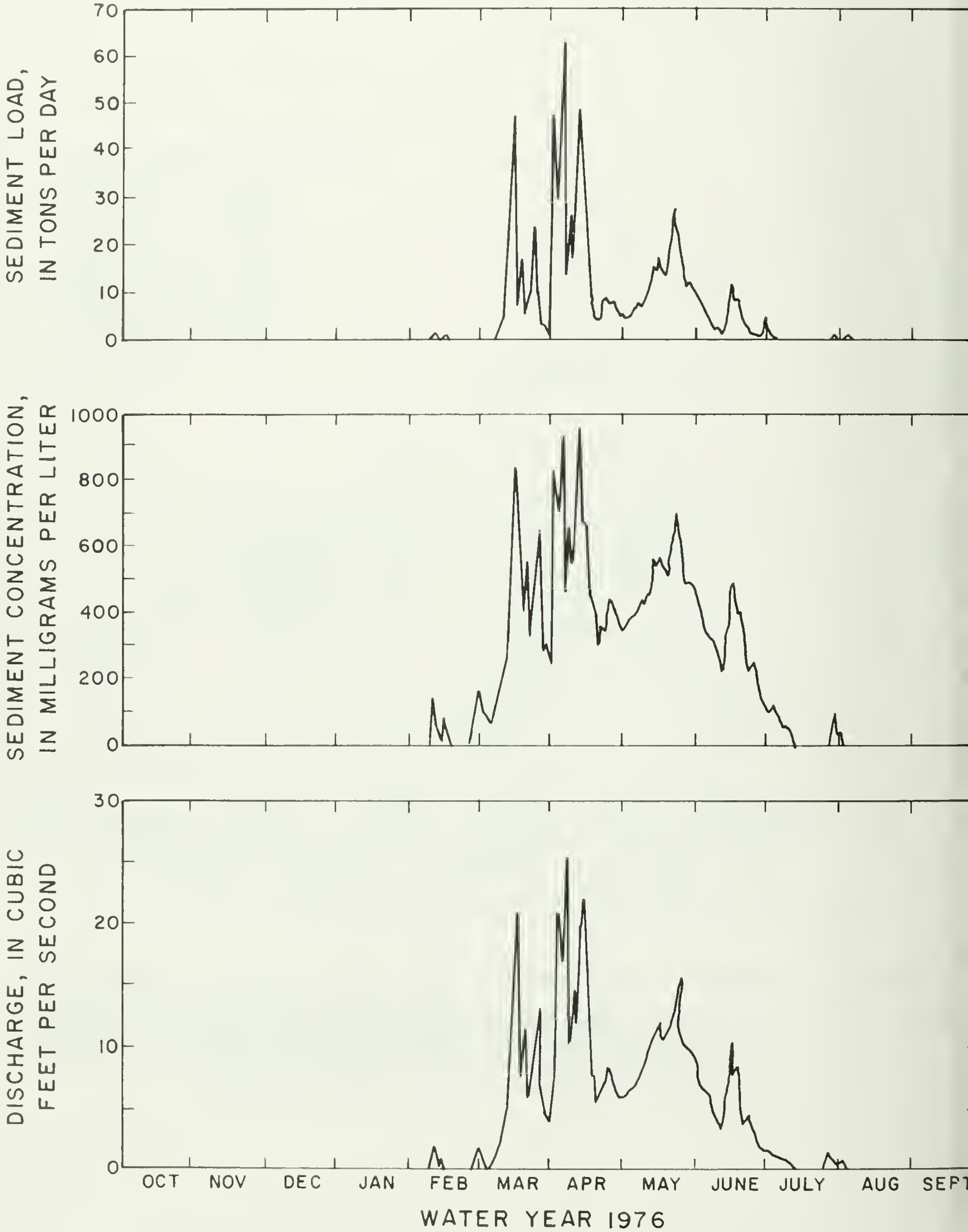


Figure 33 .—Daily discharge, suspended-sediment concentration, and suspended-sediment load at streamflow station 09216527 Separation Creek near Riner, Wyoming (1976 water year).

Natural factors affecting sediment concentrations derived from the study area include rate, location, and quantity of snowmelt, channel slope, soil type, drainage density, vegetal cover, and rainfall rate and duration. Man-made factors affecting sediment yield are stock reservoirs on tributaries to the main channel and on the main channel itself. The density of domestic stock grazing in the area also affects sediment yields as the vegetal cover is affected.

Figures 34 to 37 show sediment concentration and load in relation to discharge at station 09216525 and 09216527 (sites S-25 and S-29). Comparison of the relations shows that sediment concentrations and loads are about the same at the two sites. There is an insignificant amount of sediment picked up or deposited in the reach of channel between the two sites.

Samples were also analyzed for percent of material coarser than 62 microns. These analyses showed the greater amount of material in transport to be finer than 62 microns. Sediment of this fine-size class is transported as wash load, even at low velocities and will be deposited only in impoundments or in flood plains when overbank flows recede.

Measurement of turbidity was also made on samples collected at the time of sediment samples. Turbidity values are listed in table E3, app. E and range from 50 Jackson Turbidity Units to 550 Jackson Turbidity Units at station 09216525 and from 20 Jackson Turbidity Units to 760 Jackson Turbidity Units at station 09216527. The high values of turbidity are due to the fine nature of sediment in transport.

During the period of data collection, very little sediment was produced from the headwaters to about site S-20a. An increase in sediment concentration was noted for a short distance downstream from this point. The channel itself is not a major sediment contributor but acts as a conveyor. Sediment material is primarily fine material carried in suspension and deposited in impoundments constructed across the main channel.

Channel characteristics

The physical characteristics of a stream channel are highly related to its flow and sediment discharge. Many aspects of the environment, such as aquatic biology, are in turn dependent upon the physical characteristics of the stream channel. Thus, a change in the flow regime or sediment discharge will result in changes to the physical characteristics of the channel, which can in turn affect certain aspects of plant and animal life.

The characteristics of a stream channel are related in part to the hydraulic properties of its flow. Figure 38 shows relations of width, mean depth, and mean velocity as functions of discharge for the stream channel near station 09216527 (site S-29). The relations show that width, depth, and velocity of the stream increase as discharge increases.

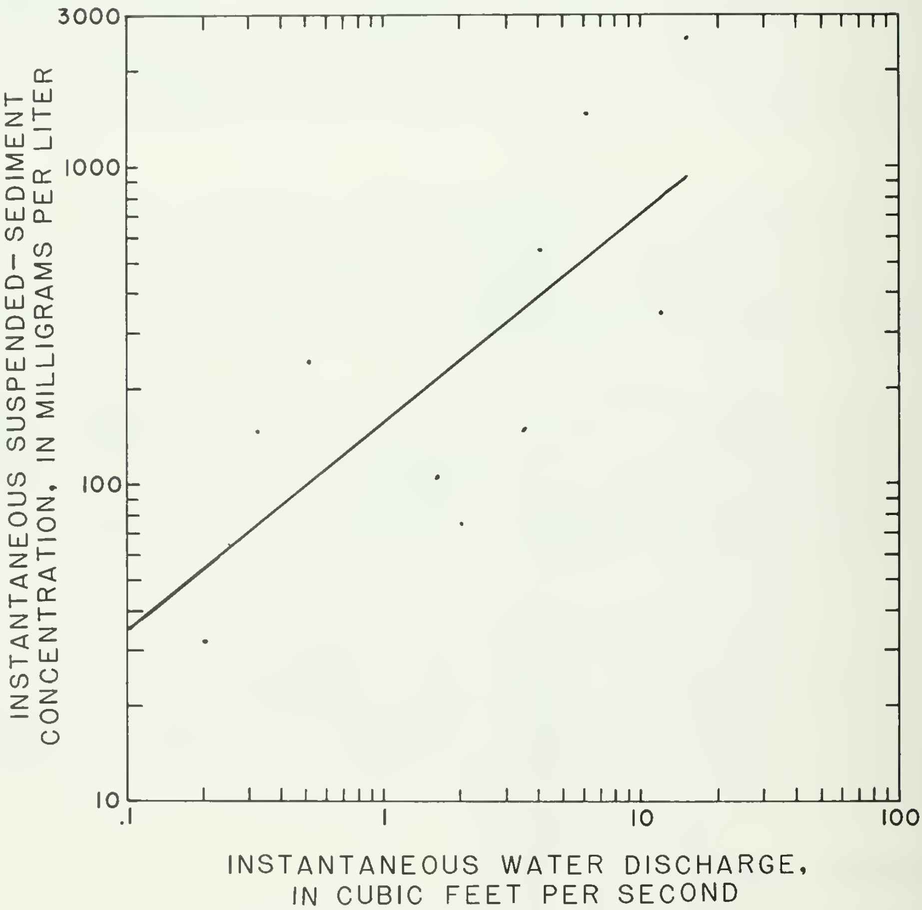


Figure 34 .—Relation of suspended-sediment concentration to water discharge at station 09216525 Separation Creek at upper station near Riner, Wyoming (1976 water year).

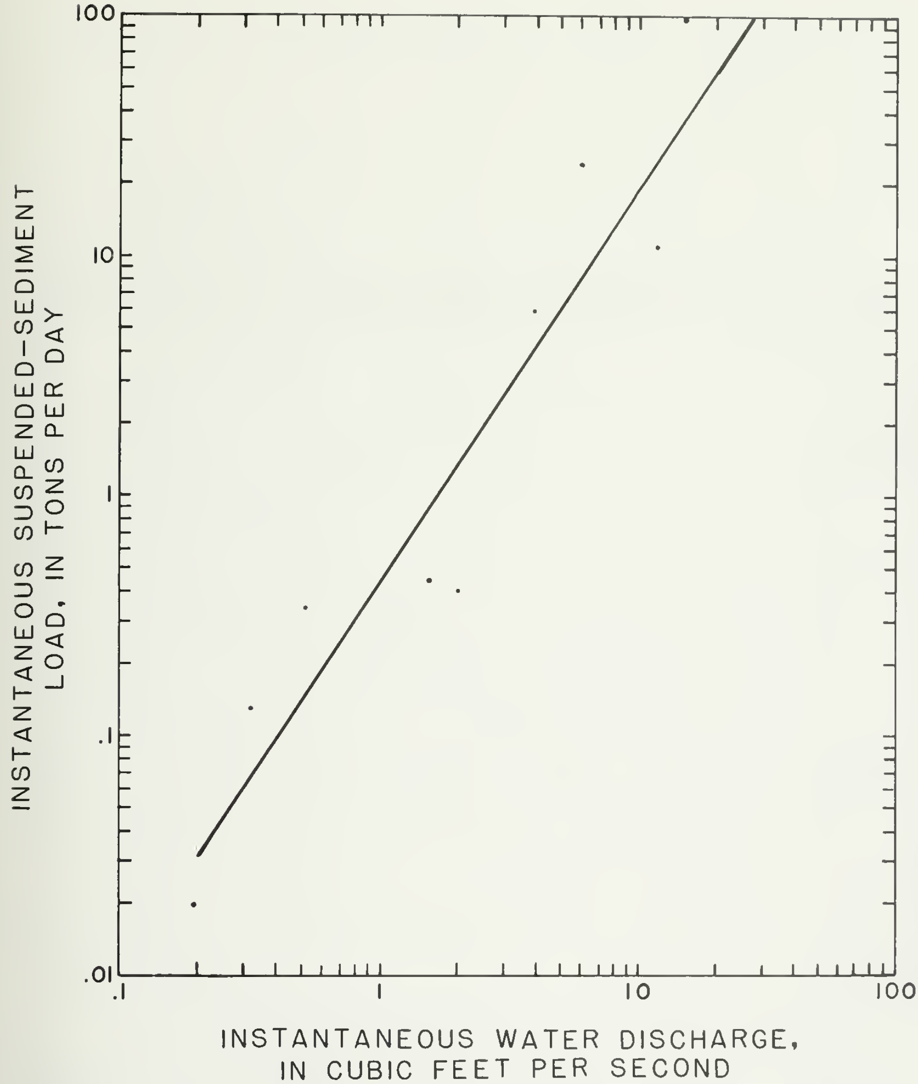


Figure 35 .—Relation of suspended-sediment load to water discharge at station 09216525 Separation Creek at upper station near Riner, Wyoming (1976 water year).

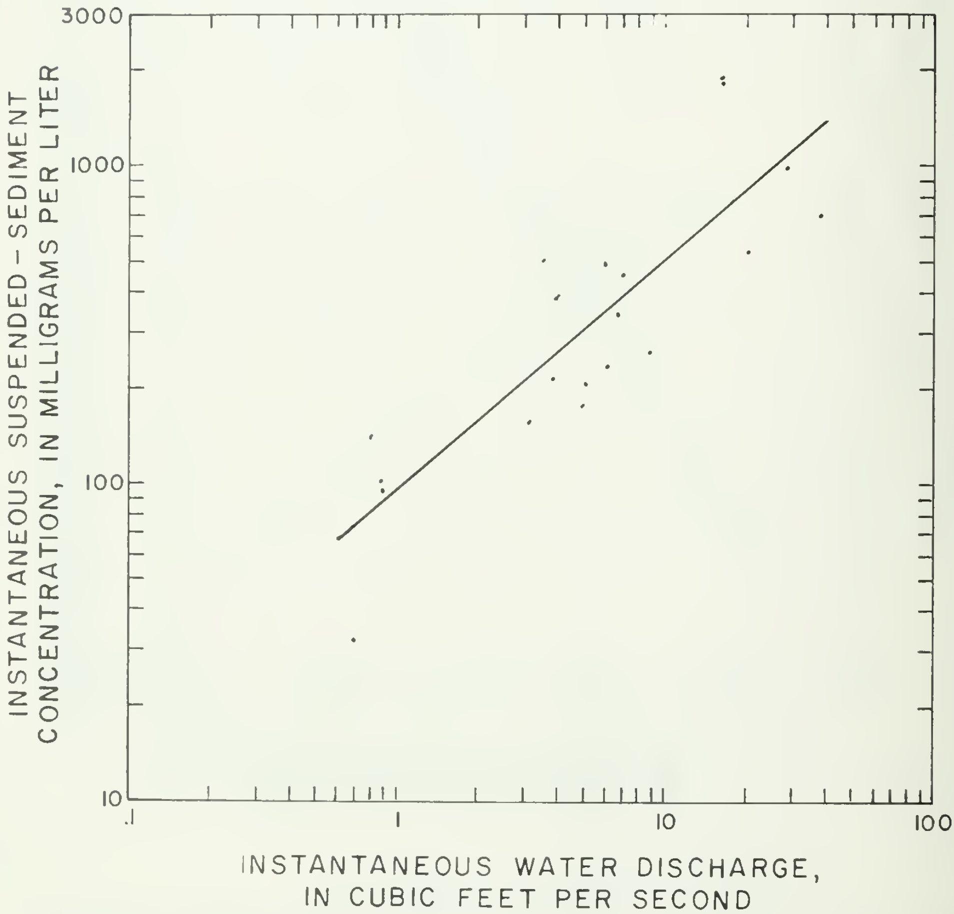


Figure 36 .—Relation of suspended-sediment concentration to water discharge at station 09216527 Separation Creek near Riner, Wyoming (1976 water year).

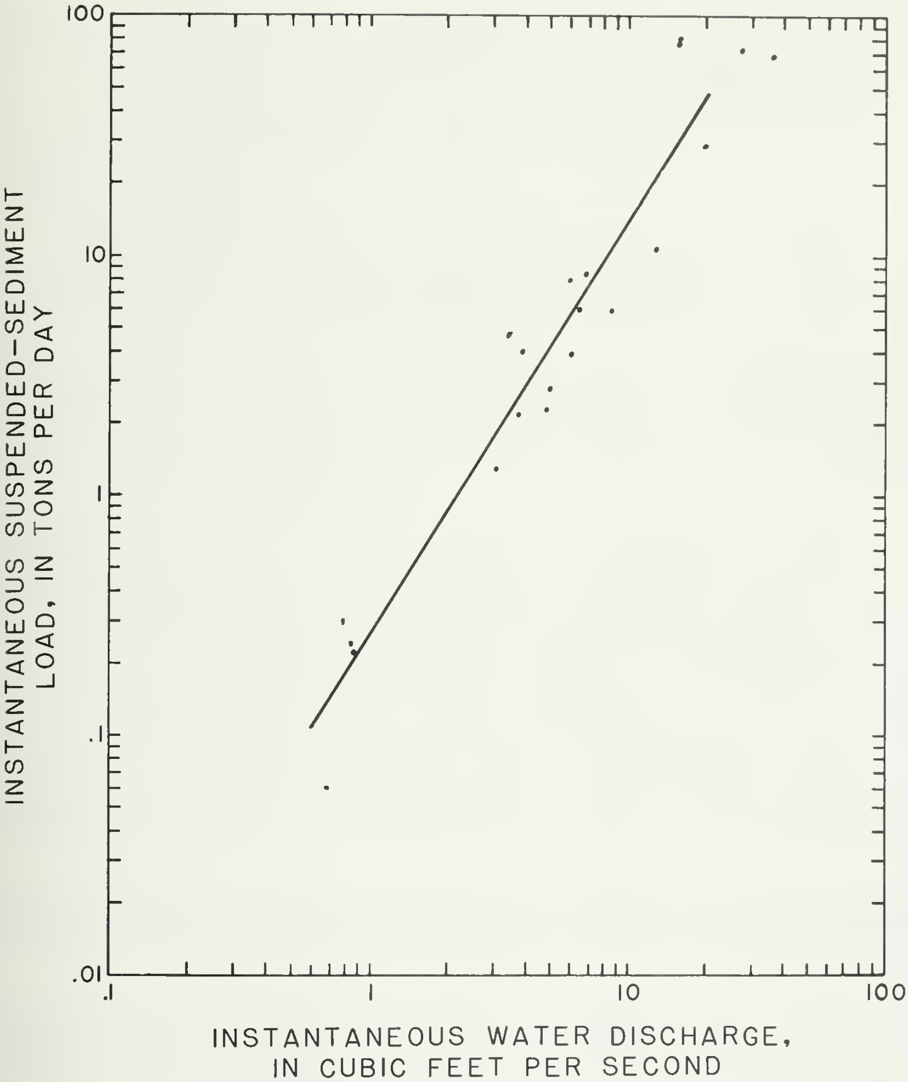


Figure 37 .—Relation of suspended-sediment load to water discharge at station 09216527 Separation Creek near Riner, Wyoming (1976 water year).

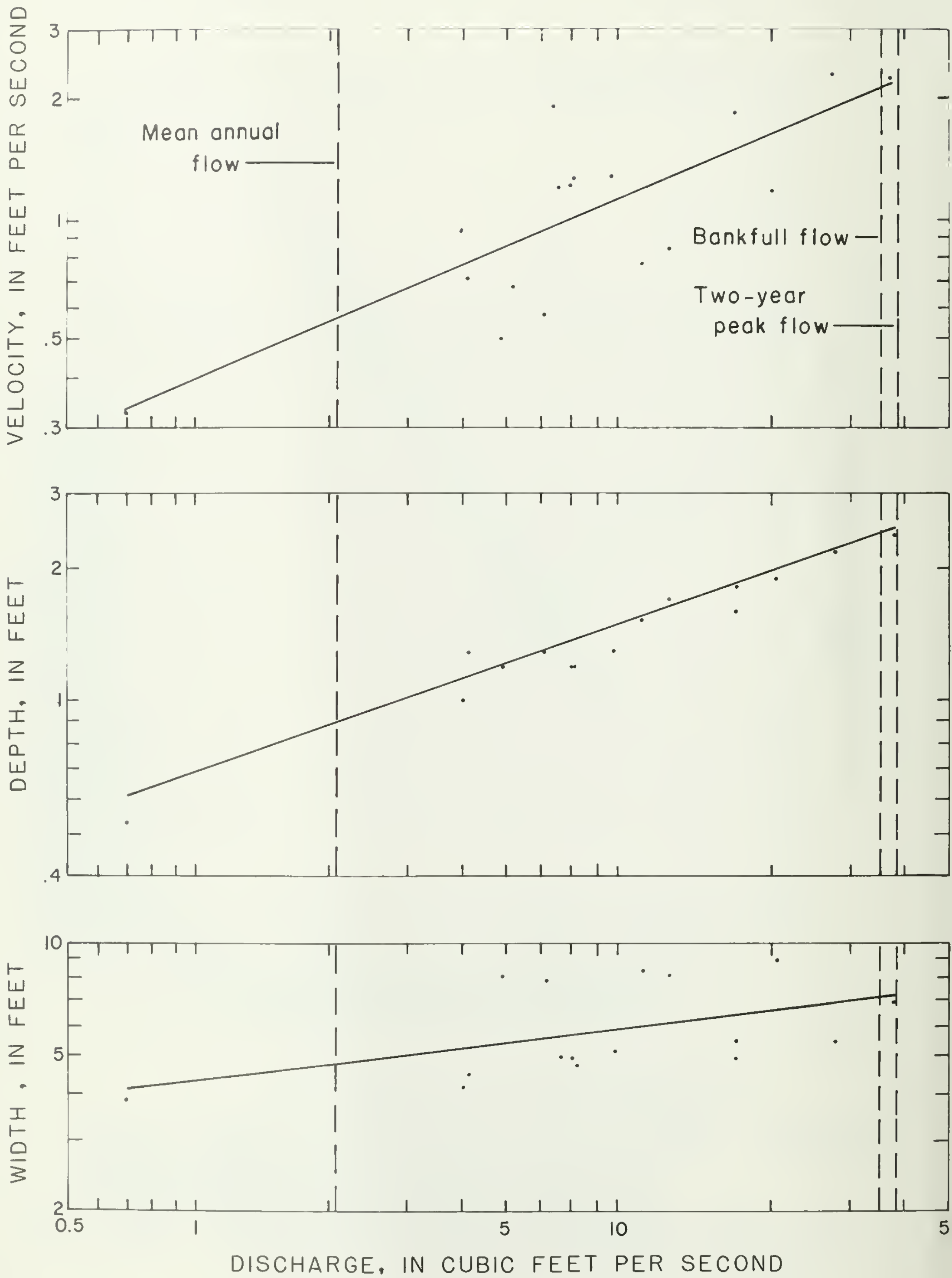


Figure 38 .—Changes of width, mean depth, and mean velocity with discharge at a channel cross section, station 09216527 Separation Creek near Riner, Wyoming.

Figure 39 is a graph showing streambed elevation and drainage area in relation to downstream distance of Separation Creek. The total length of the stream is about 82 miles, and it has an elevation drop of about 2,050 feet in that distance. The major portion of annual runoff originates from the hilly area above an elevation of about 7,000 feet.

Figure 39 shows important increments of drainage area added at each point where a tributary joins the main stem of Separation Creek. Important increments of drainage area contribute directly to the main channel, and the largest increment is contributed by the inclusion of the Fillmore Creek drainage. As the graph shows, the abrupt inclusion of this large drainage area and thus the addition of significant flow does not abruptly influence the general profile of the main-stem stream. Figure 40 is a logarithmic plot of the streambed profile. The logarithmic plot shows that except for a few local inequities, the streambed can be mathematically described by a log-linear relation.

Additional physical characteristics of the streams are shown in figures 41 and 42. Figure 41 shows the relation of drainage area to stream order for Separation Creek and its tributaries in the general area of the study site. Stream order is defined as the position of a stream in a channel network. First-order streams are unbranched fingertip tributaries; second-order streams receive tributaries of the first order only; third order streams receive one or more tributaries of the second order but may also receive first-order streams, and so on. Maps of 1:24,000-scale were used to determine stream order, stream length, and drainage area.

Figure 42 shows the relation of stream length to drainage area for Separation Creek and its tributaries in the general area of the study site.

Figures 39 to 42 show that the physical properties of stream channels in and near the study area can be quantitatively expressed and related to other basin features. Review of the relations shows the drainage of Separation Creek to be in a state of equilibrium. The slope and channel characteristics of the stream have adjusted to provide, with the available discharge, just the velocity required for the transportation of the load supplied from the drainage basin.

Aquatic biology

Separation Creek is similar to many plains streams in Wyoming in that its headwaters are spring fed and perennial while the lower reaches are intermittent. This division plays an important role in the character of the aquatic biological community. The community in the lower reaches, downstream from site S-20, is limited to organisms which can produce a resting spore stage (akinete) as do some blue-green algae, or are able to hibernate by burrowing deep into the banks and bottom mud as do adult predaceous diving beetles and dragon fly nymphs. The rest of the community in the lower reaches are washed in from the headwaters during high-flow periods. App.E, table E4 lists phytoplankton and periphyton genera found in Separation Creek and table E5 lists benthic invertebrates found in Separation Creek.

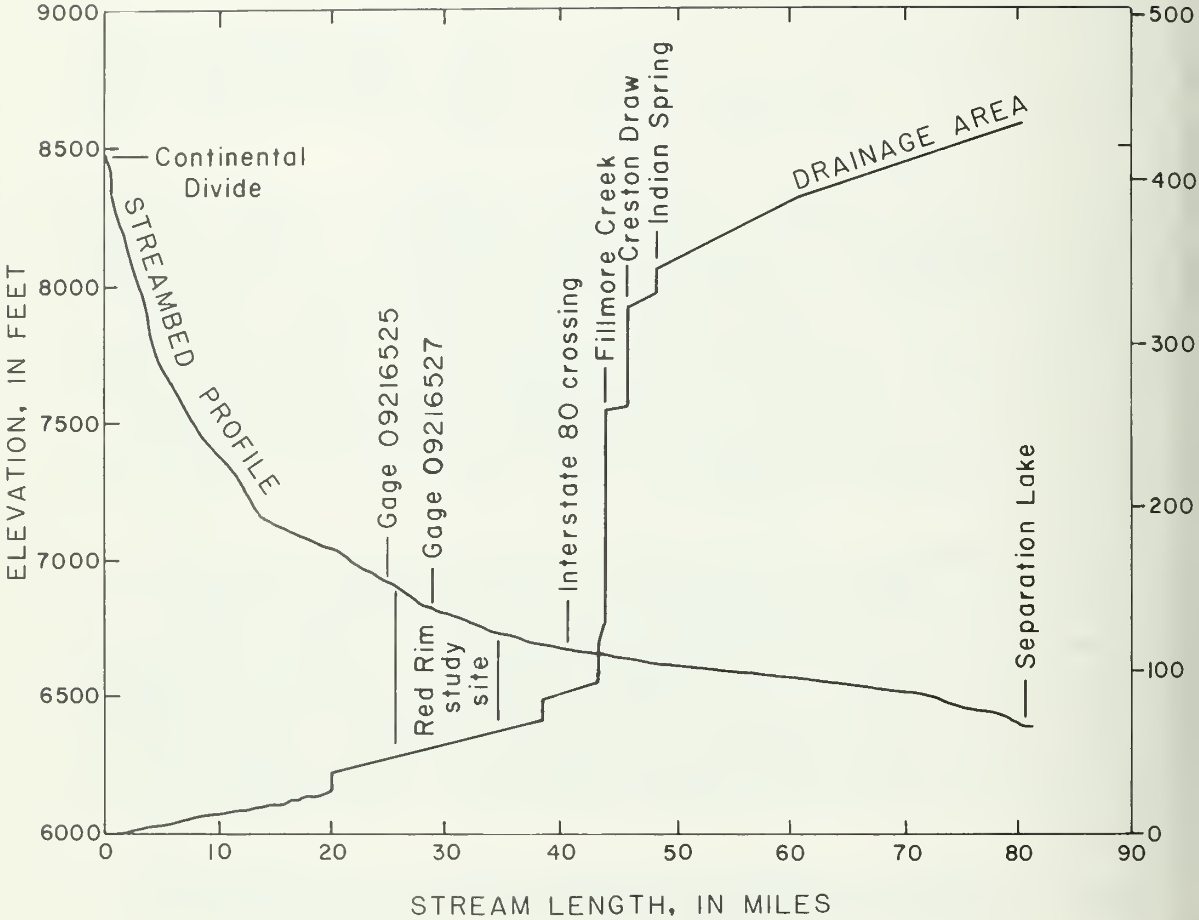


Figure 39 . —Stream elevation and drainage area as a function of downstream distance, Separation Creek, Wyoming.

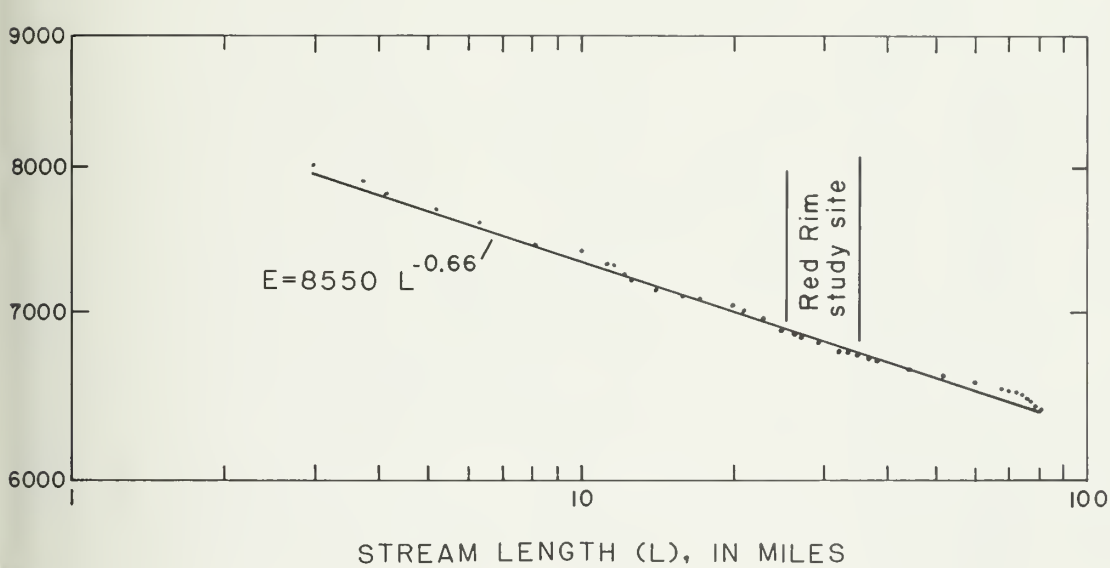


Figure 40 .—Stream elevation versus downstream distance, Separation Creek, Wyoming.

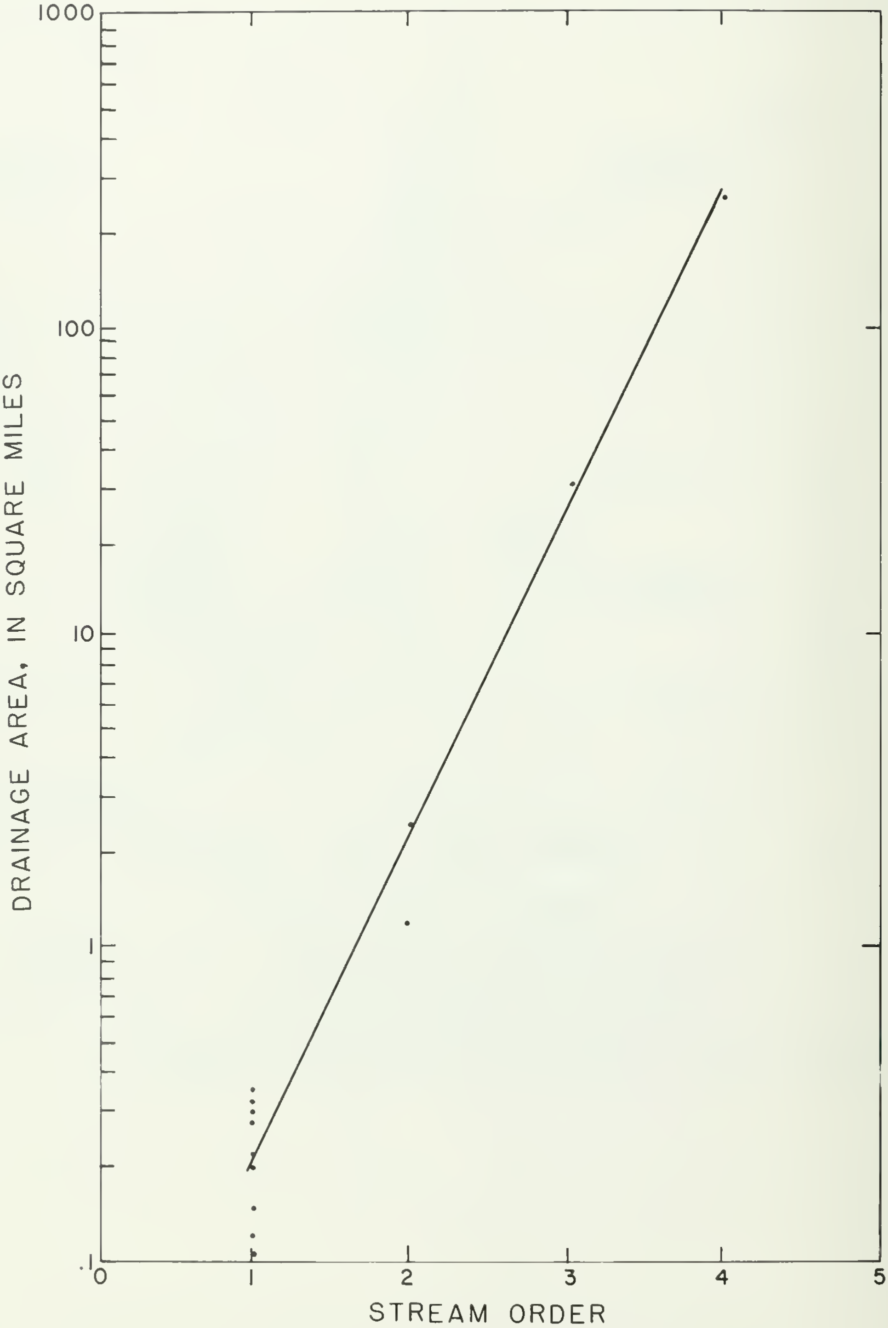


Figure 41 .—Relation of drainage area to stream order, Separation Creek and tributaries, Wyoming.

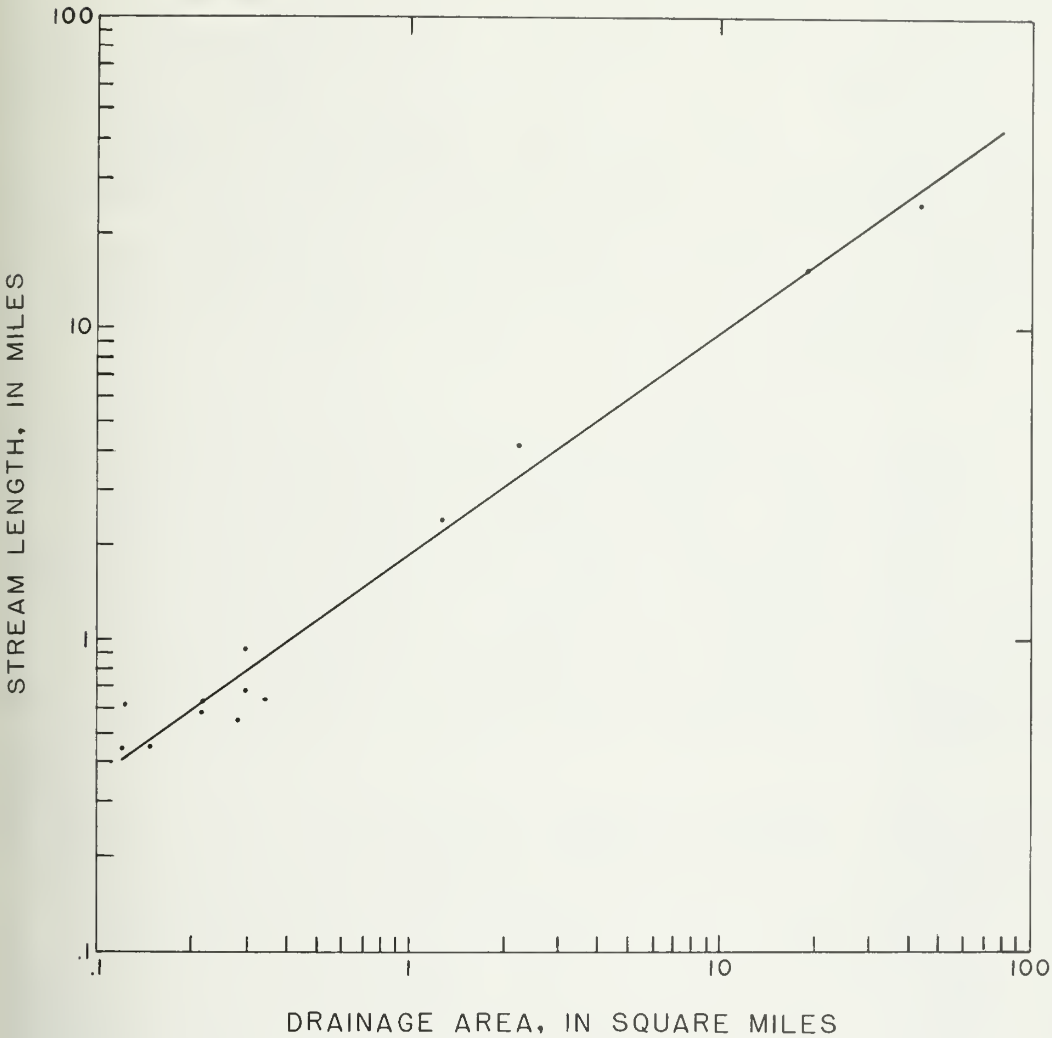


Figure 42 .—Relation of stream length to drainage area, Separation Creek and tributaries, Wyoming.

The water in the perennial reach upstream from about site S-20 is characteristically cooler, less tubid, carries less suspended sediments, and is rich in organic debris due to numerous beaver ponds. The type of organisms present reflect the same characteristics for their life requirements. Some of the dominant algal genera present are the green algae, Spirogyra and Ulothrix, the diatoms, Synedra and Fragilaria, and a euglenoid, Tribonema. All of these organisms prefer cold, clear, hard water with a pH between 7.0 and 8.5, and high concentrations of dissolved oxygen. Spirogyra has a definite preference for spring areas as do many diatoms. Fragilaria has a high tolerance for organic matter while the green algae, Chlamydomonas, acts upon organic debris to release organic nutrients which in turn can be utilized by other organisms present. Some of the organisms, primarily Tribonema, are more prominent in faster currents, which are believed to aid in the uptake of phosphates, and are limited by slower moving, warmer water. Figure 43 shows the relative abundance of phytoplankton genera in the waters of Separation Creek.

Dominant benthic invertebrates of the stream include Sphaeriidae (fingernail clams), Baetidae (May flies), Gammaridae (scuds), Glossiphoniida (leeches), Physidae (pouch snails), Limnephilidae (caddis flies), and Hydracarina (water mites). Like the algae, they prefer hard, alkaline water that is cool, clean and has a high oxygen concentration. The main food stuff, except for Hydracarina, which is parasitic upon other insects, is a mixture of decaying small mineral particles and algal cells. The family Baetidae is classified as a "sprawler" or an organism especially evolved for walking on organic debris rather than attaching itself to the undersides of rocks as do many May fly larva. The May fly is restricted to moving water due to its respiratory requirements and feeding habits.

Separation Creek downstream from about site S-20 is characteristically warmer, more turbid, has higher sediment concentrations, and is intermittent During the high-flow period, the dominant organisms are drift organisms, washed in from the upper, more productive reaches. Of importance is the decrease or disappearance of these organisms and the development of a different community which is more tolerant of the low-flow conditions. Blue green algae, such as Oscillatoria and Lyngbya develop first, probably because of their preference for temperatures that are cooler than most blue greens require. The pioneer general of green algae, Ankistrodesmus, is found early in the year along with the diatoms, Gomphonema and Epithemia. As the water level decreases and the temperature increases, these organisms give way to those which are more tolerant to high concentrations of dissolved solids such as Scenedesmus, Carteria and Cosmarium (green algae), Amphiprora (a diatom with a particularly high salt tolerance), Anacystis and Anabaena (blue greens which flourish in such conditions). As the stream stops flowing and temporary pools form, the algae disappear due to a lack of available nitrogen, except for Anabaena which is capable of incorporating atmospheric nitrogen into cell protein. Anabaena eventually replaces the other algae and forms a pure collection. Beyond this point in time, dissolved oxygen decreases rapidly due to decomposition of algal cells. A toxin (hydroxylamine) may form from decomposing blue-green proteins and, without some inflow, the pool will dry up.

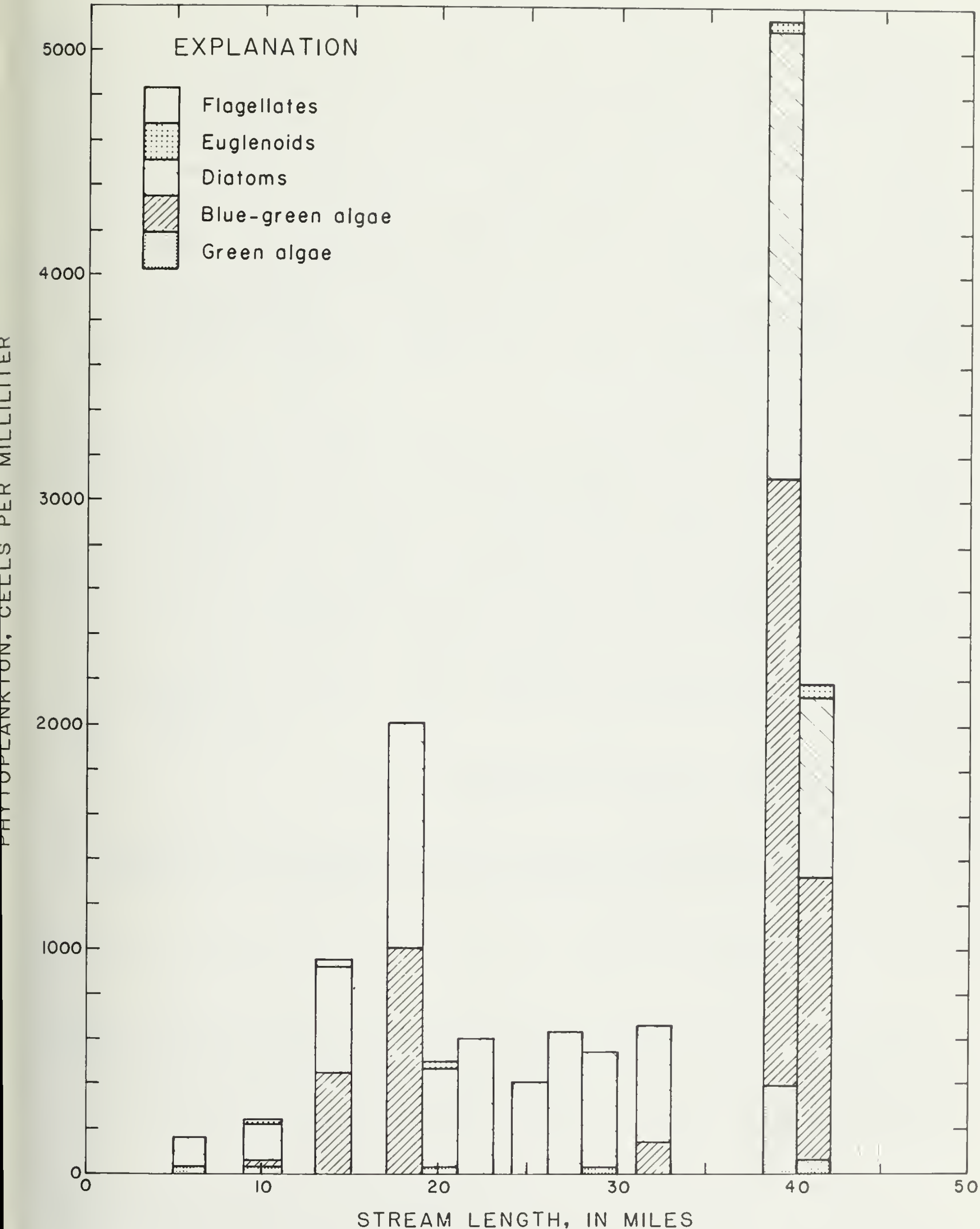


Figure 43 .—Relative abundance of phytoplankton in the waters of Separation Creek, May 12 and 13, 1976.

Benthic invertebrates that are native to the final pools and not dependent on being washed in during high flow are Dytiscidae (predaceous diving beetles), Agrionidae (dragon flies), and Corixidae (water boatman). These organisms may be present throughout the stream but due to their ability to hibernate deep in the stream mud, they may survive dry spells, to emerge again in the spring. In addition to the organisms listed as dominant in the upper reach, which are carried into the lower reach during the high flow, organisms such as Culicidae (mosquitoes and phantom midges), Gerridae (water striders), and Perlodidae (stone flies) may flourish in quiet pools. As the pools disappear in mid to late summer, so also do the benthics. Some organisms will lay their eggs on the available substrates, others will emerge as adults and fly upstream to lay their eggs in perennial pools and others, as noted above, will burrow into the bottom or banks of the pool. Some will survive until the next wet period and some will not be able to prevent desiccation.

Algal Growth Potential (AGP) was sampled twice during 1976 to help define the biologic relationships in Separation Creek. AGP is dependent upon the availability of dissolved nutrients to the test organism (Shoaf and Lium, 1976). As nutrients become available, the AGP increases. However, when an active community of phytoplankton and periphyton is present, the available nutrients will be utilized, taken out of solution, and AGP will decrease. Where dissolved nutrients are limiting, both AGP and algal populations will decrease. Figure 44 shows the observations of Algal Growth Potential in the waters of Separation Creek.

The following general statements summarize the aquatic biology of Separation Creek:

1. A greater diversity of habitat in a locality results in a greater diversity of organisms.

2. Great fluctuations from the normal conditions result in a small diversity of organisms and an increase in numbers of the organisms present.

3. The longer a locality is stable, the richer and more stable the community becomes.

Separation Creek, particularly in the lower reaches, does not have a diverse habitat for aquatic organisms and any given locality is never stable enough to develop a rich community structure. This instability and continual change in the chemical and physical character of the stream results in a low diversity of organisms and an increase in the number of those present until the habitat disappears.

The above system could be altered through development primarily by increasing or decreasing the amount of surface flow in Separation Creek. An increase in flow could increase the diversity and stability of the aquatic community while a decrease in flow could decrease the diversity and stability to a level below the present condition.

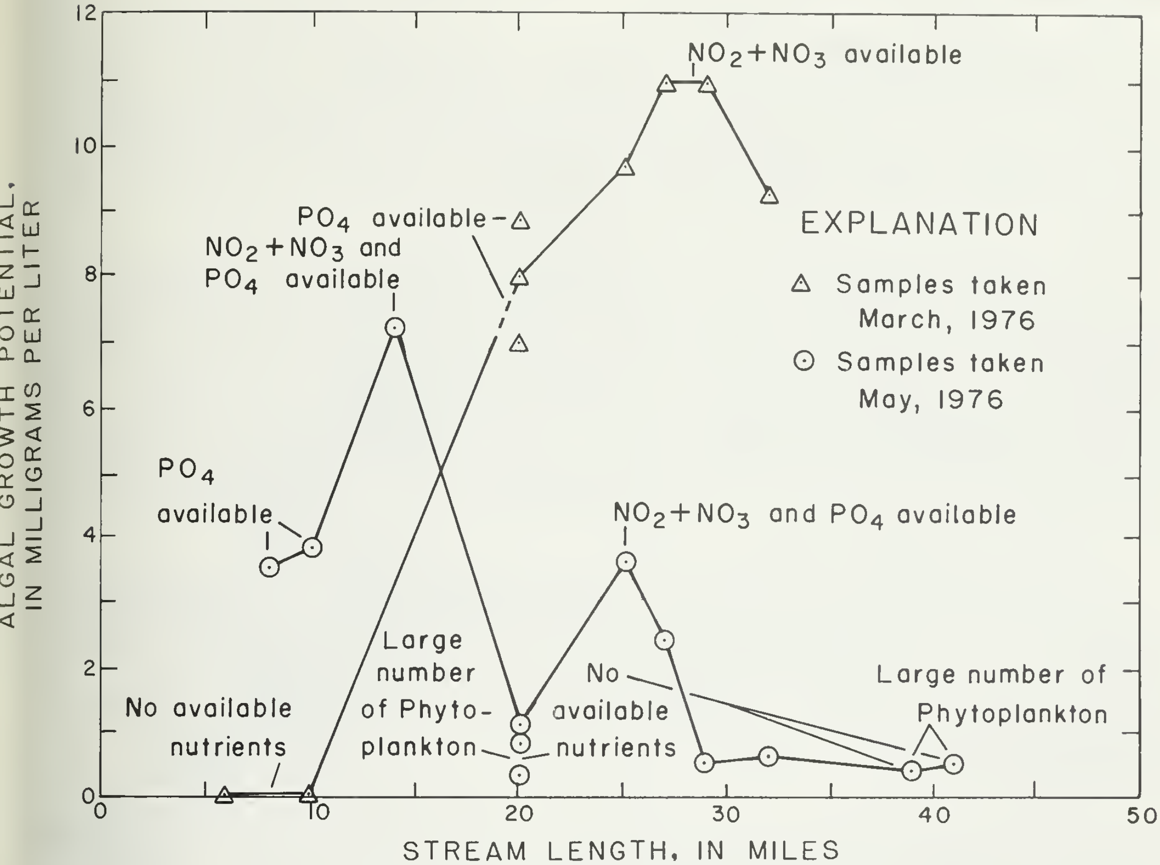


Figure 44 .—Observations of Algal Growth Potential for waters in Separation Creek.

Ground Water

Availability and distribution

The Fort Union Formation underlies the entire Red Rim EMRIA site. The formation consists largely of lenses of sandstone, siltstone, shale, and coal. Most of the lenses pinch out within one mile but the basal sandstone, more than 500 feet thick, persists over a distance of more than 12 miles. This cliff-forming sandstone, stained red by iron salts, forms the Red Rim for which the site is named.

Two wells pumped by windmills and used for watering livestock are in the sections designated in the EMRIA site. Of these, one in Section 34 of Township 20 North, Range 90 West is 300 feet deep and the other, in Section 8 of Township 19 North, Range 90 West is 110 feet deep. Of 10 exploratory holes drilled by the Bureau of Reclamation, one in Section 18 of Township 19 North, Range 90 West and 190 feet deep, found water and was cased as an observation well. Figure 45 shows the location of these and other wells and the potentiometric surface of water in the Fort Union Formation.

The potentiometric surface shown in figure 45 is a composite surface as each lenticular bed in the Fort Union, except for the basal sandstone, is so discontinuous that it is doubtful that any two wells penetrate the same beds. The map indicates that the Red Rim is a recharge area and that ground water flows from it to Separation Creek or northwestward into the Great Divide Basin to discharge by inter-formational leakage.

Downstream from about site S-20, Separation Creek is an intermittent stream--it flows in some reaches during dry weather though it is dry upstream and downstream. The flow during dry weather is largely transmitted as underflow through the alluvium. Where the alluvium is constricted so that its cross-sectional area is reduced, water appears on the surface and the stream flows. If the cross-sectional area increases downstream, the flow may again infiltrate the streambed into the alluvium and the stream is dry. The length of the flowing reaches increases after killing frosts in the fall kill phreatophytic vegetation and thus reduces transpiration of ground water from the alluvium. Figure 46 shows the area underlain by alluvium of Separation Creek near the Red Rim site as mapped by Sanders (1974). Five holes were augered to determine the thickness and character of the alluvium and to permit measurement of the water level in the alluvium and sampling of the water. Water levels measured in these auger holes provided the basis for the potentiometric contours shown in figure 46. The results of water sampling from the alluvium are also shown in the figure and will be discussed later.

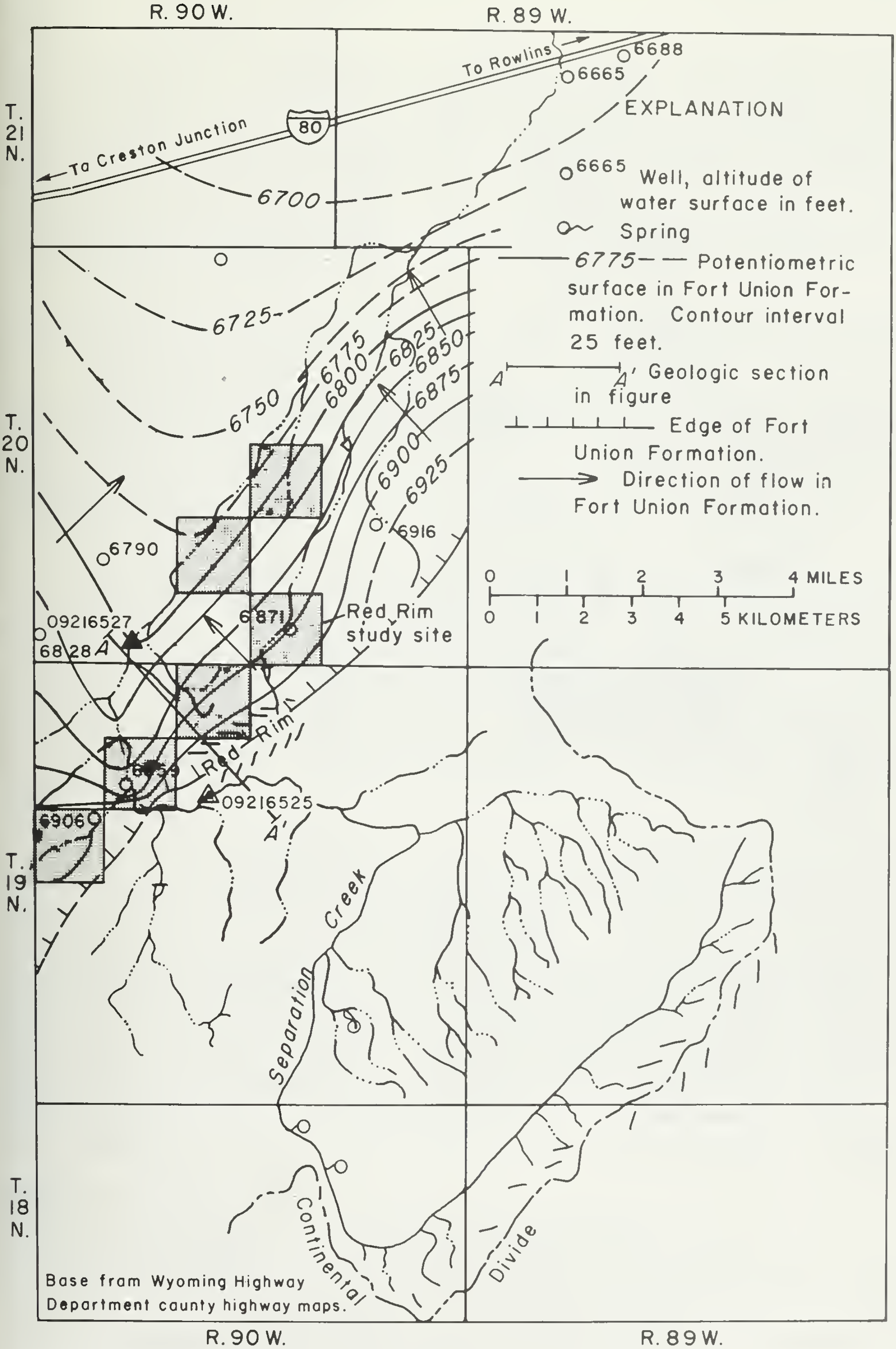


Figure 45. — Potentiometric surface of water in the Fort Union Formation and locations of wells and springs.

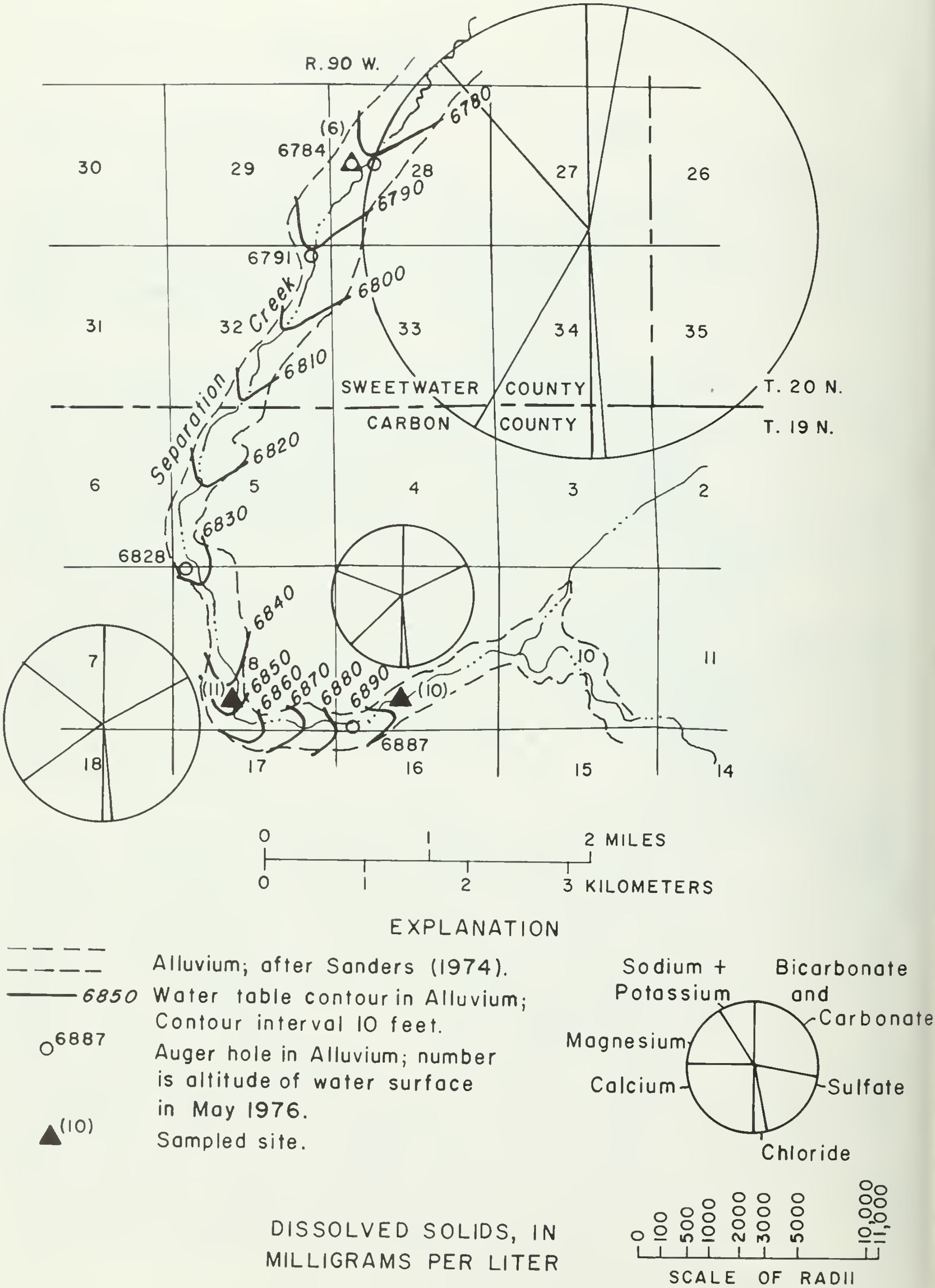


Figure 46 .— Alluvium in Separation Creek valley with water-table contours and quality of the water from alluvium.

Figure 47 is a geologic section drawn to show the relation of the ground water to the coal in the Fort Union Formation. In the upland parts of the area, the water is deep enough that little dewatering would be needed at the 200-foot depth that has been proposed as an economic depth limit for surface mining. Near Separation Creek, however, a depth of 200 feet would require considerable dewatering not only from the saturated Fort Union Beds but from induced recharge from Separation Creek and its alluvium.

Figure 48 is a distance-drawdown graph that can be used to estimate the effect of given amounts of withdrawal in dewatering the Fort Union.

Because of the discontinuity of beds in the Fort Union and the presence of major boundaries to ground-water flow, such as the edge of the formation and Separation Creek, figure 48 should be considered as a rough estimate. Aquifer tests at specific sites under consideration for mining would be needed for accurate determination of pumping rates needed for dewatering.

The transmissivity of 150 feet squared per day used in preparing figure 48 was estimated from the specific capacity (0.7 gallons per minute per foot of drawdown) of a well in Section 8 of Township 19 North, Range 90 West, using diagrams in Walton (1962, p. 12-13). A "slug" test conducted on a test hole in Section 18 of the same township yielded an estimated transmissivity of 44 feet squared per day. The test hole is open to 20 feet of coal and shale while the well is open to 45 feet of sandstone. Hydraulic conductivity of the coal and shale is about 2.2 feet per day and that of the sandstone is about 3.3 feet per day.

The highest recorded yield from the Fort Union Formation in the vicinity of the Red Rim is 325 gallons per minute with a drawdown of 150 feet from a well 3,800 feet deep drilled as an industrial-supply well about 7 miles west of the Red Rim site. The specific capacity of this well is about 2.2 gallons per minute per foot of drawdown, and transmissivity estimated from specific capacity is about 540 feet squared per day. This well seemingly penetrates the basal sandstone of the Fort Union which underlies the major coal beds and thus will not be dewatered. The basal sandstone could be an important source of water for mining or reclamation purposes. The drawdown effects of pumping from an aquifer with this transmissivity and an assumed storage coefficient of $1X10^{-4}$ are shown in figure 49.

Quality of ground water

Six wells that tap water from the Fort Union Formation were sampled as part of this study. One spring producing from the Mesa Verde Formation at its contact with the overlying Lewis Shale was also sampled. Results of the analyses are listed in tables E6-E8, appendix E, and are represented by pie diagrams in figure 50.

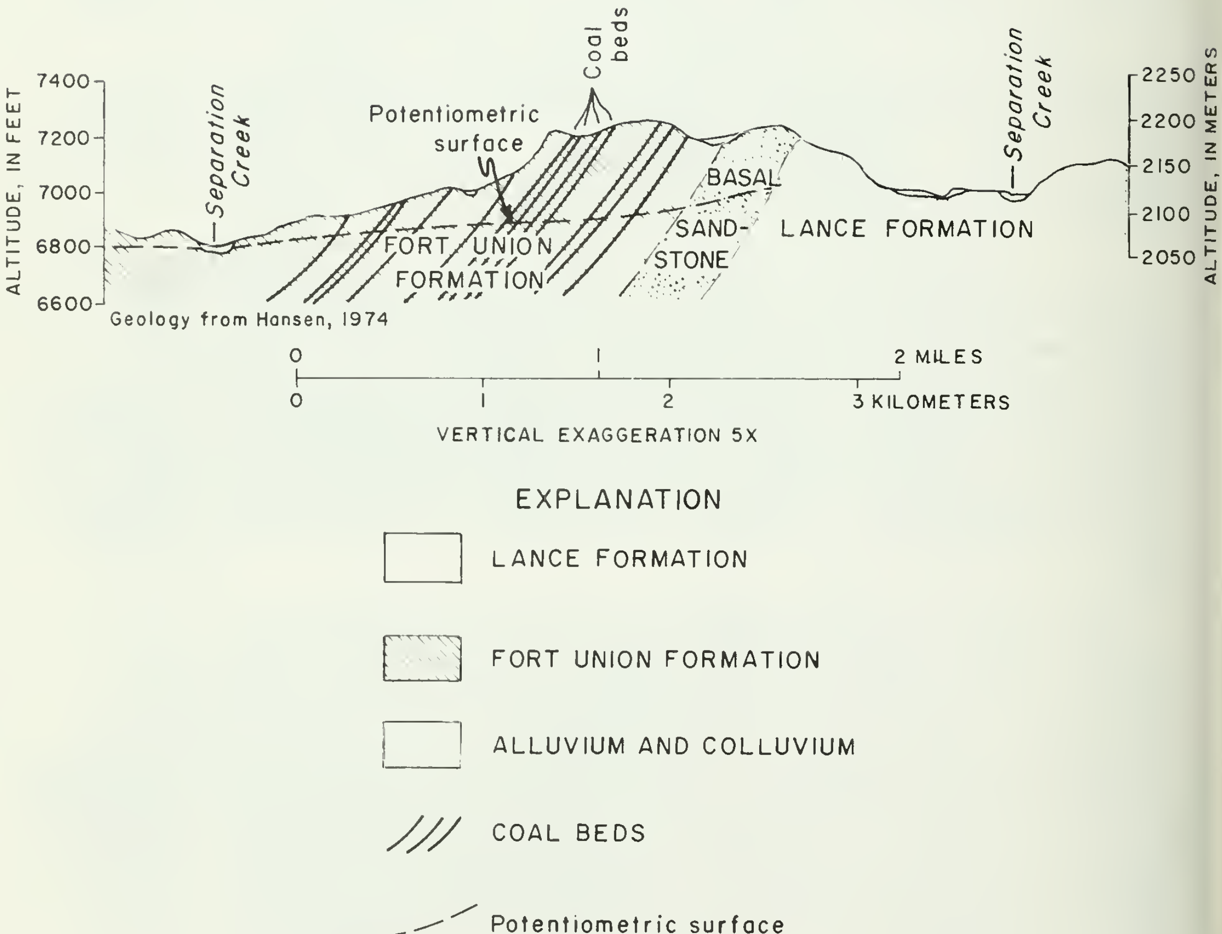


Figure 47.—Geologic section A–A′ showing the relation of the potentiometric surface of water in the Fort Union Formation to coal beds (Location of section shown on plate 2).

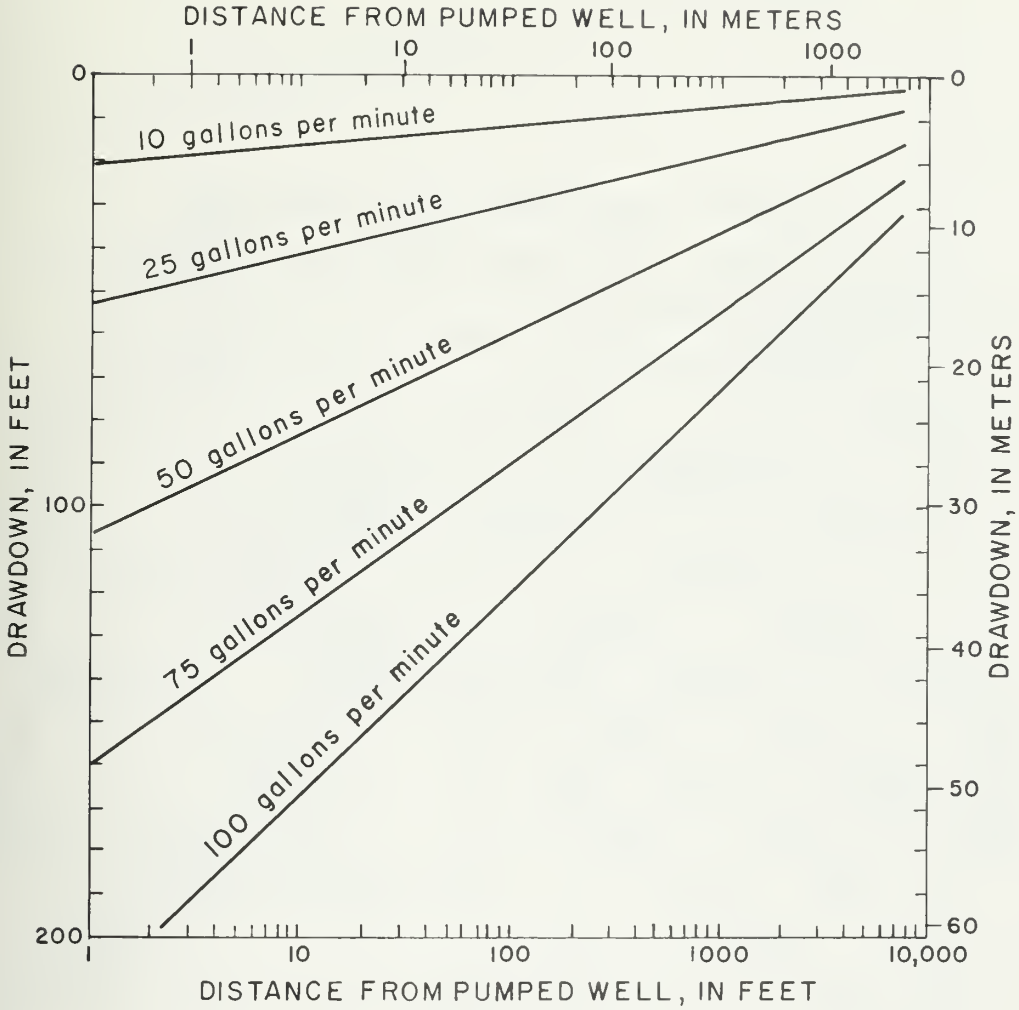


Figure 48 .—Drawdown resulting from pumping a well in the Fort Union Formation having a transmissivity of 150 feet squared per day and a storage coefficient of 1×10^{-4}.

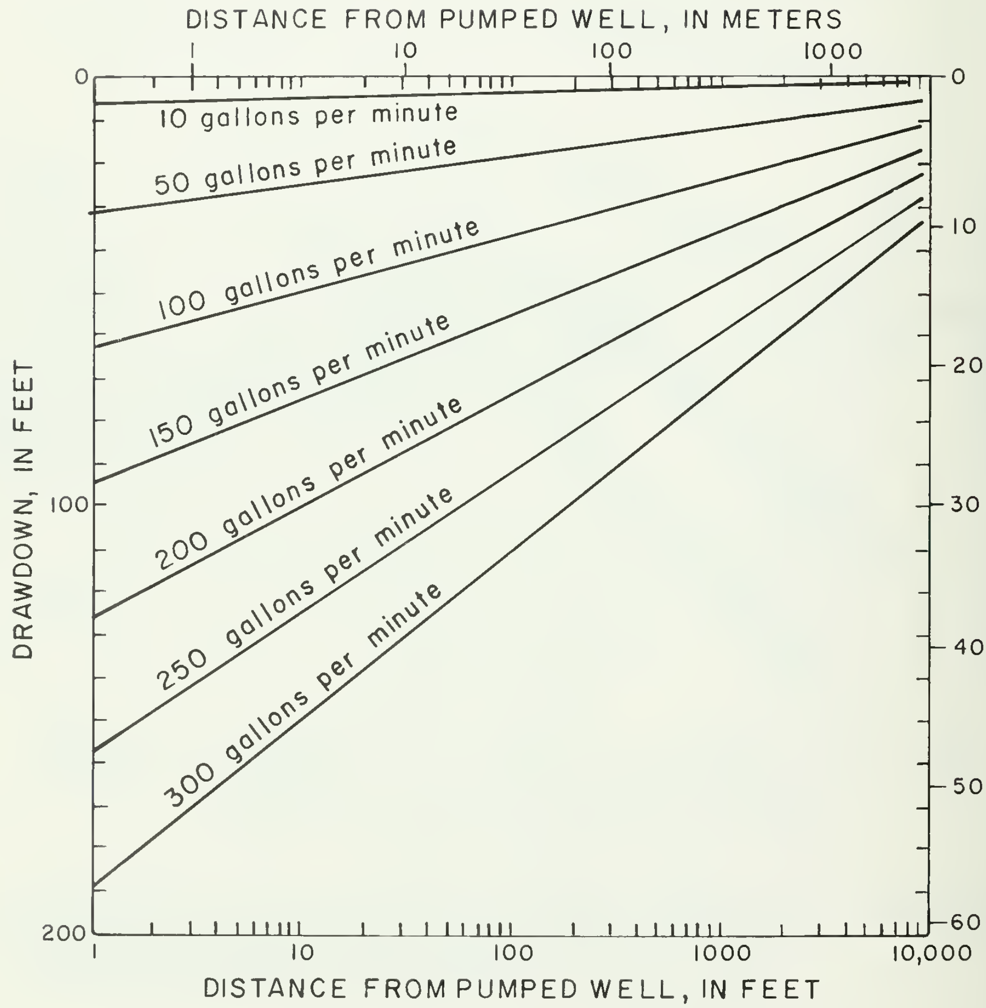


Figure 49 .—Drawdown caused by pumping a well in the basal sandstone having a transmissivity of 540 feet squared per day and a storage coefficient of 1×10^{-4}.

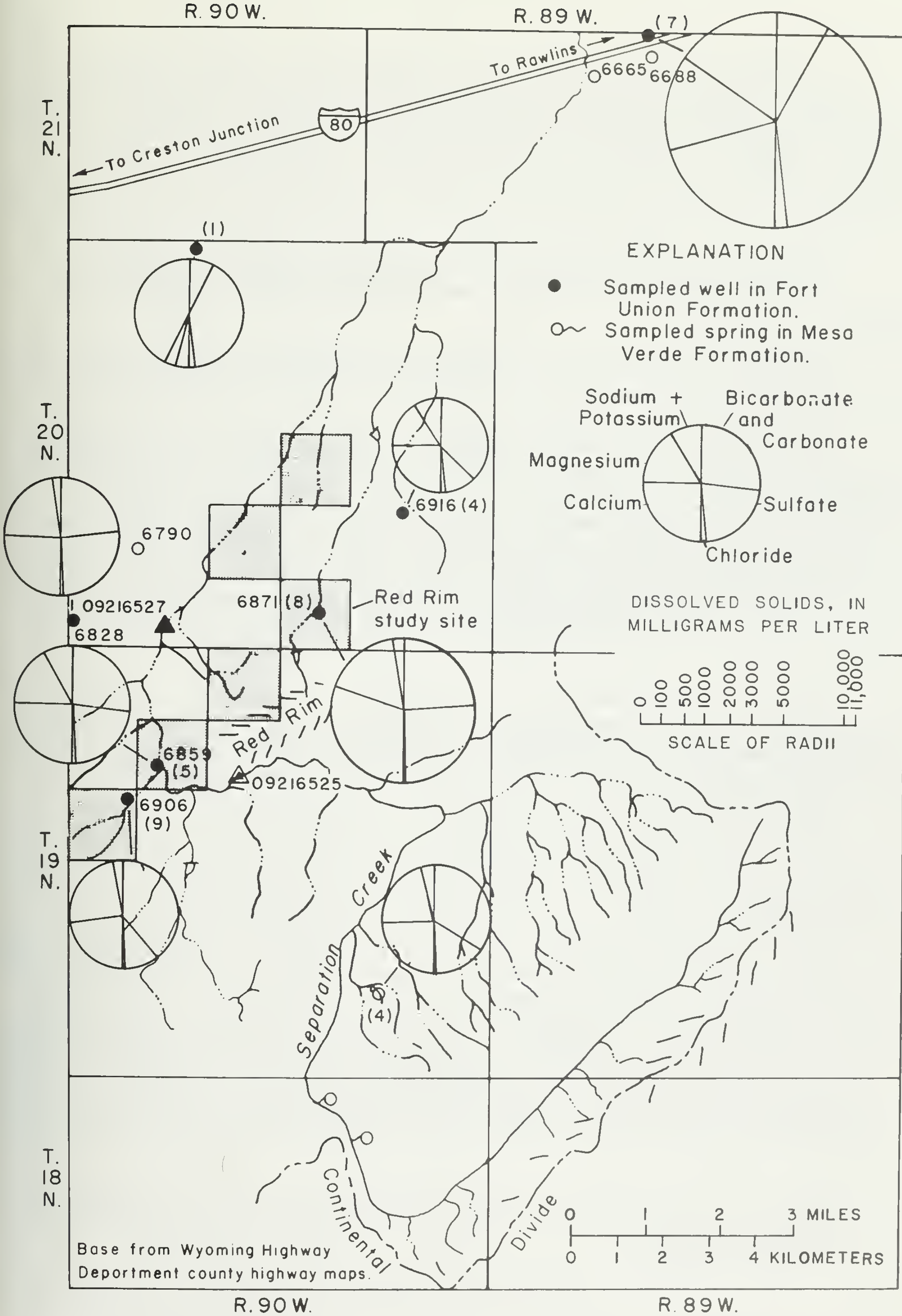


Figure 50 .—Water quality of wells tapping the Fort Union Formation and of a spring in the Mesa Verde Formation.

In addition to the major elements represented in the pie diagrams, analyses included many minor elements and radiological chemistry of some wells. No toxic levels were noted in any of the analyses. Iron is commonly present in water from the Fort Union in amounts sufficient to cause objectionable staining and taste if the water is used for domestic purposes.

Sulfate concentrations in most sampled wells are high enough to have a cathartic effect on humans, and some are high enough to cause scours in livestock.

Despite these limitations, the water is generally satisfactory for livestock watering--its main present use.

One auger hole provided a sample from the base of the alluvium of Separation Creek. Two samples from intermittent flowing reaches of Separation Creek were collected to represent shallow water in the alluvium. The analyses are represented by pie diagrams in figure 46. The water from the auger hole has a dissolved-solids concentration of more than 10,000 milligrams. Epsom salt (magnesium sulfate) is a major proportion of the dissolved solids, and the water is unsuitable for most uses. Sulfates also comprise much of the dissolved solids in the two shallow samples. The water could be cathartic to livestock.

The use of ground water for irrigation as a means of reclaiming mined lands may be contemplated. The samples analyzed present a low to medium sodium hazard but a high to very high salinity hazard if used for irrigation. They should be used only on well-drained soil on salt-tolerant crops.

Effects of mining on area hydrology

Surface water

Because the major part of annual runoff originates above 7,000 feet elevation, mining of the Red Rim study area would have little effect on the quantity of runoff for Separation Creek. Relatively little runoff occurs from the Red Rim study site (fig.22). Changes in flow characteristics of Separation Creek due to surface mining of intervening drainage between S-25 and S-39 would be insignificant with the following exception. If dewatering is necessary to the extent that production water has to be pumped to the channel, base flow of the stream would be increased from its present value of zero cubic feet per second.

Because little runoff occurs from the study site, mining would cause insignificant changes to water quality in Separation Creek with the following exceptions:

1. Local sediment concentrations and loads much higher than those shown in figures 34-37 would occur in Separation Creek during periods of runoff from the study site. This increase would continue until a vegetal cover is restored.

2. Rechanneling of the stream to allow mining would have the most significant effect on water quality, as it would take a number of years before the overall channel would stabilize. During this period, sediment concentrations and turbidity would be increased.

3. If production waters were pumped into the channel, sediment and dissolved-solids loads would be increased. Pumping of more than about 0.5 cubic foot per second to the channel should be discouraged.

Re-establishment of disrupted or destroyed channels and drainage systems should be made with consideration of the physical relations shown in figures 39-42. Figure 40 shows the streambed of Separation Creek upstream and downstream from the study site would be affected by rechanneling. If rechanneling is necessary, the stream should be re-established after mining to a distance and slope conforming with those shown in figures 39 and 40. Figures 41 and 42 should be used as guides for layout of drainages for reclaimed areas. For example, figure 41 shows that for an area of about 2 square miles a drainage pattern with a second-order stream would be required. Figure 42 shows that for a drainage area of 2 square miles, at least 3.2 miles of stream channel would have to be constructed to simulate a natural channel network.

Ground water

If mining is carried out below the potentiometric surface of water in the Fort Union Formation, dewatering of the mines will be necessary. The amount of pumping needed for a given depth of dewatering can be roughly estimated by use of figure 48 despite the limitations imposed by the complexity of the aquifer. An actual engineering design would require aquifer testing at the specific places to be dewatered. Discharge of water will lower water levels in other wells and their potential yields--the extent depending on the locations of the wells and the discharge points and the hydraulic characteristics of the part of the aquifer dewatered.

Mining near or beneath the valley floor of Separation Creek will necessitate dewatering and may result in recharging the Fort Union Formation with water from the alluvium. This water is inferior for most uses to that in the Fort Union and will degrade that in the Fort Union if it is not completely pumped out. If it is pumped out of dewatering wells or sumps, it will pose more of a disposal problem than will the better water from the Fort Union.

As mined-out pits are backfilled with spoil, the hydraulic characteristics will be markedly altered. At first, as loose material is placed in the pit, porosity and permeability (especially vertical permeability) will increase over that of the original consolidated material. The

material may occupy a volume as much as 25 percent greater than its original value (Hadley and Keefer, 1975). This "swell factor" is additional porosity over the original. As the spoil compacts with time, this porosity and permeability is gradually reduced. The spoil is a heterogeneous and chaotic mixture similar to glacial till except that the method of emplacement may induce a rough stratification as well as affect compaction. Dragline-emplaced spoils in the Powder River Basin had permeability as much as 100 times as great as spoils emplaced by scrapers and bulldozers (Rahn, 1976, p. 28-29). Most of this difference is probably caused by the compaction by the machinery but dragline emplacement can also induce a rough stratification with coarse rubble (chaotically oriented) at the base of the spoils. As compaction proceeds hydraulic characteristics will probably approach those of till formed of similar materials (siltstone, sandstone, and shale).

As recharge water percolates through spoil, it will come into intimate contact with relatively impermeable material through which little water has previously infiltrated. Because this material has been so slightly leached, it may be rich in leachable material, and this will be introduced into the recharging water. Additional study is needed to ascertain the effects of percolation through spoil. In the Powder River Basin (Rahn, 1976, p. 40) water from spoils was found to contain significantly greater concentrations of hardness, calcium, magnesium, sulfate, and dissolved solids than native ground water. The specific conductance of 1:5 extracts from fragmented core samples (appendix C, p.C6-C11) ranged from 40 to 2,380 micromhos.

Recommendations for additional study needs

Results of study at the Red Rim site will have transfer value to other areas of southwestern Wyoming that contain strippable coal in the Fort Union Formation. The hydrologic study was based on a short period of data collection. Longer-term definition of the hydrologic relations should be made. Additional study would be directed toward: 1) Long-term records for description of the water resources and hydrologic processes that presently exist; 2) refinement of predictive models that can be used to describe future conditions, including reactions to mining; 3) refinement of models to allow transfer or hydrologic information to other areas; and 4) documenting changes due to mining of the area.

Although the overall hydrology of the area was determined in this study, future efforts should be directed toward better definition of the "microhydrology" of small drainages. A model of the total water budget should be developed for small drainage basins.

RECOMMENDATIONS FOR RECLAMATION OF SURFACE-MINED AREAS

Legal Requirements of Mine-Land Reclamation

Federal - Attempts have been made during the last two sessions of Congress to enact a strip mining bill which provides for reclamation of all lands disturbed during mining operations. Both of these attempts failed in enactment of a law because of Presidential veto.

In the absence of a Federal strip mining law, the United States Department of the Interior designed and published in the Federal Register, regulations designed to open up Federal coal lands to surface mining under stringent controls to protect the environment. These new standards went into effect on May 17, 1976, and meet the President's goal to insure that only those Federal coal lands that can be mined in an environmentally sound manner, are mined. The new regulations were endorsed by both the Environmental Protection Agency and the Council on Environmental Quality. Performance standards for mine operators include the requirement to restore the approximate original countour of mined land, establish vegetation at least equal in density and performance to the original vegetation, and protect against hazards to public health, safety and offsite damage. Exploration, mining and reclamation may take place only after a plan has been approved, and a performance bond must be submitted and maintained at all times to cover the cost of all remaining reclamation.

The Bureau of Land Management will administer coal leasing, permits, and licensing, and Geological Survey will have authority over coal exploration, mining, and reclamation.

State of Wyoming - In 1973, a new law was passed, entitled the Wyoming Environmental Quality Act of 1973. It is designed to regulate land development and control the pollution of air, water, and land within the State. The 1973 act pertains to all types of underground mining as well as surface mining. Some of the important features with regard to reclamation are:

1. It repeals the 1969 act.

2. It establishes a nine-man board to administer the act in place of the Land Commissioner. This board is appointed by the Governor.

3. It requires issuance of licenses and permits and sets provisions for denial of permits.

4. It requires advertisement of mining permit applications, and provides for filing objections to the application and public hearings.

5. It requires land disturbed by mining to be returned to a use of equal or greater value than its prior use.

6. It requires a mining plan showing the nature and extent of the mineral resources, the land to be mined, and a description of mining operations with a time schedule.

7. It requires a reclamation plan prior to issuance of a mining permit. This plan must include:

A. Cost estimates for reclamation.

B. Maps showing extent of reclamation, which must be periodically updated.

C. Methods of regrading and recontouring the affected land.

D. Methods of stockpiling, preserving, and returning the topsoil.

E. Methods and plants used for revegetation.

8. It requires the prevention of water pollution from mine spoils.

9. It sets time limits on reclamation and can raise the surety bonding requirements.

Local - To the best of our knowledge, no local strip mining laws have been enacted or are now being enforced.

Objectives of Reclamation

The lands which overlie the coal seams of the Red Rim area are rangelands that have in the past been considered to be of low economic value for livestock and wildlife grazing. In order to strip mine the coal resources, it is necessary to remove the topsoil and overburden materials and to replace these materials after removal of the coal, in a manner to return the land to the land uses similar to those prior to mining. These uses were livestock and wildlife grazing, wildlife propagation, watershed management, and limited recreation activities.

In order to return these lands to a desirable form and land uses similar to those uses prior to mining, it is necessary to know what the lands are like prior to strip mining with special emphasis on the soils, vegetation, water, and animal resources. The preceding information provided in this report fulfills this need.

Reclamation of mine spoils must also recognize that the basic ecology of the area is drastically changed from its original state prior to mining. Mine spoils are, in reality, new and unique ecosystems in regard to their attributes and ecological processes, and must be throughly understood and evaluated before recommendations are made for the reclamation of the mined land. An area that has been disturbed by surface mining seldom reaches the same ecological equilibrium that existed prior to the disturbance. This is especially

true when major alterations of soil, topography, and living organisms will be made during the disturbance such as will be made in the removal of coal in the Red Rim area. Strip mining, is a drastic environmental change. Successful reclamation can be accomplished only when thorough analysis planning is completed prior to the actual mining. Factors being considered in this study include evaluation of the overburden material and how it must be shaped and treated in order to support desirable plant life, prevent soil erosion both by wind and water, prevent water pollution (either ground or surface waters) and maintain or enhance the aesthetic values.

Alternative Plans for Reclamation

Selection of Materials to be Placed on Surface as Planting Media - Reference to sections "Land Suitability" and "Overburden Suitability" indicates materials of choice which can be utilized as planting media. It can be said, as a general rule, that existing surface soils are to be preferred as a source of topping (or revegetation) material since they are usually suitable within the area, and generally represent medium-textured materials with favorable physical condition, permeability and water holding capacity. Referral to the above-cited sections will additionally reveal a considerable quantity of suitable overburden materials is also present. Quantities of suitable materials to be placed on the surface are adequate within the area.

Handling and Placement of Soil and Overburden Material - The primary concern in these operations on the Red Rim area will likely be in methods to be employed in utilizing as much suitable topsoil material as possible along with techniques of separating suitable overburden materials and proper disposal or placement of toxic ones.

Suitable surface soils will be removed and stockpiled and there will be sufficient suitable material for revegetation purposes on this site.

Unsuitable materials (saline, soidic, acidic) should be identified through more detailed specific studies during mining operations. Wherever possible, these materials should be placed at a depth greater than 5 to 10 feet below the reconstructed surface.

Probable resulting soil profile - Detailed reconstructed soil profiles will not be attempted for this report. Suffice to say, the above procedures should result in at least 2 to 3 feet of medium to moderately coarse-textured soil material of good permeability, moderate water holding capacity, nonsaline, and nonsodic for use as a plant growth media.

Placement and Isolation of Toxic Materials - Wherever toxic materials are encountered, care should be exercised to assure disposal in such a way and at such depth and in such a manner to assure that these materials will not come in contact with the root zone of reestablished vegetation or pollute ground waters. It would be advisable to dispose of these materials at depths below 15 feet from the reformed surface.

Shaping of surface - Final determination of shaping of the surface following mining operations will likely be a mutual decision reached by BLM and the mining company. Determination of aesthetics is subjective at best, and the most desirable form and function of the land will likely evolve with time as mining operations progress. However, the following generalizations can be made at this time.

Effective shaping of spoils to some preconceived design is essential to these lands so that they blend and harmonize with the adjacent undisturbed topography and land form, both for aesthetic purposes and to assure a minimization of drainage problems. In general, it is recommended for the study area that the spoil piles be placed back in the pit and graded to a rolling type of topography with slopes of 4:1 or less. To facilitate reestablishment of vegetation, topographic plans for the area should maximize north and east facing slopes, since south and west facing slopes are drouthier and hotter, thus making them more difficult to revegetate. Drainageways should be provided in the topographic design of the areas and grades should be flat enough to prevent gullying and excessive channel erosion. Final grading should insure that no flat areas are created which will pond water unless temporary ponding is a part of the total erosion control program for the area.

Postmining Operations or Procedures for Satisfactory Reclamation of Surface Mined Area

Characterization of Surface Material and Evaluation for Revegetation - Characterization of the replaced topsoil on the shaped spoils should be an initial step in the revegetation process. Procedures used in the land classification survey can be followed. This will provide soil data for making fertilizer recommendations, selection of plant species, proper surface manipulation, seeding methods, and postseeding management.

Selection of Species for Seeding - Based upon the vegetation study made of this site, as shown in detail earlier in the report, the following mixture of grasses, legumes, and shrubs are suitable for use in revegetating areas disturbed by strip mining and should be seeded at the rate shown as follows:

Grasses, Legumes	Seeding Rate Per Acre (Pounds)
Western wheatgrass (*Agropyron smithii*)	5
Indian ricegrass (*Oryzopsis hymenoides*)	4
Thickspike wheatgrass (*Agropyron dasytachyum*)	4
Needle-and-thread (*Stipa Comata*)	3
Sand Dropseed (*Sporobolus cryptandrus*)	1
Yellow sweetclover (*Melilotus officinalis*)	2
Rye (Nurse crop) (*Secale cereale*)	60

Shrubs	Seeding Rate Per Acre (Pounds)
Big sagebrush (<u>Artemsia tridentata</u>)	1
Winterfat (<u>Eurotia lanata</u>)	6
Nuttall saltbush (<u>Atriplex natallii</u>)	6

Other shrub species that could be considered for use in revegetation efforts are four wing saltbrush (<u>Artiplex tridentata</u>), mountain mahogany (<u>Cercocarpus montanus</u>), and antelope bitterbrush (<u>Purshia tridentata</u>). The latter two species are particularly suited to sandy soils and are important browse species for big game animals.

After the initial seeding of grasses, legumes, and shrubs is established, it can be expected that many of the other native species found in surrounding areas will invade the planted stands and over a period of many years will be similar to the vegetation composition now found in the area.

<u>Fertilization needed</u> - There will be a deficiency of phosphorus and and nitrogen on the sites to be reclaimed after mining is completed and the overburden and topsoil replaced on the disturbed area. Therefore, it is recommended that prior to ripping or chiseling the areas to be rehabilitated, they be fertilized with triple super phosphate. This will insure incorporation of the phosphate fertilizer into the top surface material where it will be readily available for plant growth and development. Nitrogen fertilizer if needed should be applied to all disturbed areas prior to or during the seeding of grasses, legumes, and shrubs. Fertilizer may be applied by broadcasting or use of a fertilizer attachment installed on the grass drill.

Later in the growing season or in subsequent growing seasons, additional light applications of nitrogen fertilizer will undoubtedly be required. The timing and rate of fertilizer should be determined by the local manager, since it will have to be based upon local observation and experience. Applications of nitrogen fertilizer after the initial one should prefereably be made by airplane, so that the surface of the reclaimed area is not disturbed thus making it subject to erosion.

<u>Preparation of Area Before Seeding</u> - Manipulation or mechanical treatment of the surface material (plant growing media) have been used for more than 30 years to facilitate plant growth and establish new seedlings and to control damaging surface and gully erosion.

After all materials are placed back in the open pit and the fine grading and topography stabilized, it is recommended that the entire area be loosened to a depth of 8 to 12 inches by ripping or deep chiseling on the countour. This operation is necessary to roughen the surface material that has become packed by equipment travel during previous operations to insure that the water intake is increased and surface runoff decreased to place coarse materials or clods on the surface to prevent wind erosion during seedling establishment.

Surface manipulation should also include such practices as pitting, dozer basins, and contour furrowing may also be used to retain soil moisture and reduce surface erosion.

In areas where drainageways collect water in sufficient quantities to cause erosion, it is recommended that water spreaders be considered. Water spreaders are systems of dikes that are designed to divert floodwater from a gully onto adjacent rangeland. Because of the normal low rainfall in this area, it can be expected that water spreaders would come into play only during periods of rainstorms that are of short duration and high intensity and during periods of rapid snowmelt.

Seeding, Methods to Use - Planting of seed may be accomplished by drilling with either an approved disk or shoe-type grass drill, an approved hydroseeder, or by mechanical or hand broadcasting in the order of preference as follows:

1. Drill seeding - Sowing the seed mixture with either an approved disc or shoe-type grass drill is acceptable. If this method is used, the drill shall be regulated to uniformly distribute the seed at the rate specified herein on the areas to be seeded. Where possible to safely operate equipment, drilling shall be done on the contour or parallel with the slopes being seeded. The drill shall be regulated so that the seed is properly placed in the soil and covered with soil to a depth not to exceed one-half inch. In the event the drill is equipped with an approved fertilizer attachment which will evenly distribute fertilizer at the recommended rate, the dry nitrogen fertilizer may be applied simultaneously with the drilling of grass seed.

2. Hydroseeding - Seeding with an approved hydroseeder will be acceptable provided wind velocities permit uniform distribution of seed and nitrogen fertilizer slurry on the areas to be seeded. In hydroseeding operations, the mixture of seed and the fertilizer specified herein shall be properly mixed with water to form a slurry. The slurry mixture shall be prepared immediately prior to application, and shall be promptly applied on the areas to be seeded and fertilized. Slurry mixtures prepared more than 1 hour prior to application are not acceptable. The hydroseeder shall be designed so as to insure seed and fertilizer being uniformly applied at the recommended rates per acre. The hydroseeder shall be equipped with a paddle-type agitator and recirculation pump that will continually stir and mix the slurry to prevent settling of solids in corners and at the bottom of the tank and maintain a uniform mixture of seed, fertilizer, and water at all times during the entire seeding operation. Immediately after the slurry mixture is applied to the soil surface, the seed shall be properly covered with soil to a depth not to exceed one-half inch if the surface area permits.

3. Mechanical broadcasting - A mechanical broadcaster of either the centrifugal type or pull type similar to fertilizer spreaders are acceptable. Any equipment of this type used for broadcast seeding shall be designed and regulated to insure that the proper seeding rate per acre is uniformly applied on areas to be seeded. When this method is used, seed and fertilizer may not be applied in the same manner simultaneously, each shall be broadcast separately.

4. Hand broadcasting - Hand broadcasting may be performed on small, inaccessible areas. Seed application may be performed by using an approved hand broadcaster or by broadcasting the seed by hand from a sack or other suitable container. Whichever means is used, the seed shall be uniformly applied at the rates suggested earlier. In the employment of this method, the seed and fertilizer shall be broadcast separately.

Fall seeding appears to produce the best results in this area. The seed mixture of grasses, legumes, and shrubs as recommended previously, should be planted as soon after final grading and the desired surface manipulation is completed in order to prevent surface erosion damage and reduce the problems of visual contrast with the surrounding landscape.

Surface Soil Protection - Protection of the surface soils from sustained high winds is essential during the winter months when precipitation is very erratic. This precipitation usually comes in the form of blowing snow. One economical method that has been successfully used to reduce surface erosion, trap winter snow and keep it on the site, as well as prevent injury to tender growing seedlings being established on a site, is to use wooden-slat snow fencing material 5 to 6 feet in height. These fences should be installed perpendicular to the prevailing winds during the winter and spring seasons and should be located about 100 yards apart or closer if needed. The snow fence can be constructed with steel fence posts that can be driven into the soil or with wood posts that are hand set. Since heavy winds are common in the area, posts should be set not more than 10 to 15 feet apart.

Another method that has been successfully used to stabilize critical areas to enable plants to become established quickly in the surface material (plant growing media) is to mulch the surface after grass, legume, and shrub seeding has been completed. Mulching nearly always shortens the time required to establish a suitable plant cover by reducing evaporation, moderating soil temperatures to promote germination and seedling growth, prevent crust, and control wind and water erosion. Any substance spread, formed or left on surface material may act as a mulch. There is an infinite variety of available mulching materials, including: straw, native hay, hay and other crop residues, sawdust, woodchips, wood fiber, bark, manure, sewage sludge, brush, jute or burlap, gravel, mulch stones, peat, paper, leaves, plastic film, and various organic and inorganic liquids.

Because of the nature of this site and availability of materials, it is recommended that the entire disturbed area be surface mulched immediately following seeding of grasses, legumes, and shrubs with either a gravel or crushed rock mulch or a native hay such as straw mulch, that is anchored by means of a mulch anchoring machine to keep it from being blown off of the newly seeded surfaces. The mulch anchoring operation should immediately follow the seeding operation. The native hay or straw mulch should be applied to the surface at a rate of not less than 2 tons per acre.

Gravel or crushed rock can also be selected from overburden material and used successfully as a surface mulching material. This type of mulch has advantages over most other mulches because it is permanent if the individual pieces are no smaller than one-eighth inch in diameter. If the gravel or crushed stone pieces are no smaller than this in size, the mulch cover will withstand a surface wind velocity of 85 mph. To control wind erosion the pieces must almost cover the soil surface (not less than 95 percent). The finer the gravel or crushed rock the less material is required to cover the ground surface.

Use of irrigation to start plantings in surface mine reclamation is a common practice. Because there is insufficient data on the quantity and quality of water that is available and the uncertainty of the reclamation plan, it is not possible at this time to determine the use of irrigation. If irrigation is proposed, the suitability of the available water should be evaluated taking into account the quantity and quality of water, species to be planted, reclaimed land characteristics, irrigation practices, and climate.

<u>Management of Reclaimed Areas</u> - After planting, fertilizing, mulching, and installation of wind barriers are completed, the entire reclaimed area should be enclosed with a barbed-wire fence which is designed and constructed in a manner to keep all livestock out of the area. The area should continue to be excluded from livestock grazing until the local manager determines that the planted vegetation is sufficiently developed and established to withstand grazing use without damaging the overall vegetative cover. In the event noxious weeds invade the rehabilitation site, the local manager should use acceptable methods of control to remove them from the plantings before desirable range plants are "crowded out" of the reclaimed area.

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APPENDICES

A. Geology

B. Coal

C. Soil

D. Vegetation

E. Study Site Hydrology

F. Biological Resources

APPENDICES

APPENDIX A

GEOLOGY

Geology

Techniques, Procedures, and Standards Used in Geologic Studies

Geologic mapping of the area was done prior to the studies for this report. Geological Survey published a geologic map of the Riner Quad in 1974 and this information was used in the present field study. The 1974 information was augmented by current information obtained from J. Hatch, Geological Survey, Coal Resources Branch.

Drilling of Hole No. 8 was accomplished using a Damco Model 1250 drill and the remaining nine holes were completed using a Portadrill Model TK, truck-mounted rig.

For the largest part of the drilling, a 4-1/8-inch diameter core was taken using a wireline setup. When use of the large wireline rig was difficult or impossible, 2-inch diameter cores were taken.

Water was used for drilling fluid and "revert," a biodegradable drilling fluid additive, was added when water losses became too great or caving of the drill hold became a problem. "Revert" has properties similar to bentonite but breaks down in a few days and does not affect the permeability of formation rock nor the quality of the ground water.

There was a geologist on the site most of the time and logging of the core was done during drilling operations when possible. Coal samples were placed in plastic bags to retain moisture as soon as they were removed from the core barrel and turned over to Geological Survey at the earliest opportunity.

The remaining core samples were transported to the Bureau of Reclamation's lab in Denver to be processed for further tests. These tests are discussed under the soils section.

Ten holes were drilled and core samples obtained from all but Hole No. 3, which was used only as a ground-water observation hole. Perforated plastic pipe was placed in Holes Nos. 3, 7, and 8 for ground-water observation and evaluation by Geological Survey.

Initially, the drill holes were located by correlation with existing data contained in the geologic map of the Riner Quad in order to intercept coal beds at a reasonable depth. As further, more complete data came available from drilling and surface reconnaissance, the hole locations were changed as necessary to gain the best possible information. A rule-of-thumb criteria, furnished by Geological Survey, was used to control the depth of holes. This is the 1:10 ratio concept which says that for every 10 feet of overburden, there must be 1 foot of coal for an economical stripping operation with a maximum depth of 200 feet.

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GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-1 LOCATION COORDS. N. E. GROUND ELEV. 6922± DIP (ANGLE FROM HORIZ.)

BEGUN 9-30-75 FINISHED DEPTH OF OVERBURDEN 7.7 TOTAL DEPTH 90.3 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Porta-drill Model TK truck mounted.	PUSH	100	7.7	0.0-7.7 SUPERFICIAL SOIL DEPOSITS
4-1/8" push samples taken 0.0'-7.7'.	Rock bit	0	10	0.0-7.7 - SAND: Fine, silty, unconsolidated, HCl reaction high, tan, (weather sandstone). (Sm)
Nx rock bit used 7.7'-10.5'.	Nx CORE	100		7.7-90.3 FORT UNION FORMATION
Nx core samples taken 10.5'-90.3'.		76	20	7.7-55.5 - SANDSTONE: (Same as above but more consolidated.) Hardness 1-3, HCl reaction high, core fragmented, cemented zones 21.4-24.0 & 50.0-51.0, tan to gray.
Revert used as drilling fluid.		100	30	
Water Losses 31.4-41.4 10% 41.4-60.3 75% 60.3-70.3 90% 70.3-90.3 95%		100	40	
Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.		99	50	
		98	55.5	55.5-57.0 - SILTSTONE: Clayey and sandy carbonaceous, hardness 3-5, iron stained joints, core pieces 1/4"-3", HCl reaction medium to high, dark gray.
		69	57.0	57.0-81.0 - SANDSTONE: Fine, silty, hardness 1-3, HCl reaction medium to high, core fragmented, silty shale from 65.0-66.0', carbonaceous silty shale from 76.5-78.0' & 80.0-81.0', no HCl reaction below 63.0'.
		100	70	
		87	81.0	81.0-87.8 - COAL
			87.8	87.8-90.3 - SHALE: Hardness 5-6, no HCl reaction, fragmented, dark gray.
			90	BOH-90.3

SUITABILITY OF OVERBURDEN: Suitable 0.0-7.7; Doubtful 7.7-45.0; Suitable 45.0-81.0; Unsuitable 81.0-87.8; Suitable 87.8-90.3.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming SHEET 1 OF 1 HOLE NO. DH-1

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GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-2 LOCATION COORDS. N. E. GROUND ELEV. 7044± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8/18/75 FINISHED 8/23/75 DEPTH OF OVERBURDEN 2.7' TOTAL DEPTH 168.9 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Porta-drill model TK truck mounted.	Push	100	100						2.7			0.0-2.7 SUPERFICIAL SOIL DEPOSITS
Two-inch diameter push samples from 0.0'-2.7'.	Core	0										0.0-2.7 - SILT: Sandy, tan gray, hardness - 1, med-high HCl reaction. (ml)
No recovery from 2.7'-6.0'.	Rock bit	0							10			2.7-18.9 - SANDSTONE: No recovery med-high HCl reaction - too hard for push samples, rockbit used from 6.0'-18.9'.
Rockbit used from 6.0'-18.9'.									18.9, 20			18.9-22.0 - SILTSTONE: Sandy, contains 4" shale layer at 19.2', hardness - 5, gray and brown, none-low HCl reaction.
4-1/8" wireline core used for remainder of hole-18.9'-168.9'.	4⅛" Core	87							22.0, 24.0			22.0-24.0 - SANDSTONE: Very fine, silty none-low HCl reaction, hardness - 5, light brown.
Revert used as drilling fluid.		66							30, 37.0			24.0-37.0 - SHALE: Carbonaceous, cracks upon drying, no HCl reaction, gray and brown to 28.0' - dark gray from 28.0'-37.0'.
Hole caved overnight from 148.9' to 125.0 and from 168.9' to 148.9'.									40, 44.0			37.0-44.0 - COAL: Subbituminous.
Water Losses		97							50			44.0-53.5 - SHALE: Silty, cracks upon drying, hardness 5-7, highly carbonaceous 52.0-52.5, gray-dark gray, no to low HCl reaction.
18.9-28.9 25%; 28.9-48.9 10%; 48.9-68.9 25%; 68.9-148.9 10%; 148.9-158.9 20%; 158.9-168.9 30%		98							53.5			53.5-59.0 - SILTSTONE: Very sandy, hardness 5-7, no to low HCl reaction, gray.
Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.									60, 62.5			59.0-62.5 - SANDSTONE: Very fine, slightly silty, hardness 3-5, breaks along bedding core pieces 1/2"-8", no to low HCl reaction, gray and brown.
		98							70, 72.0			62.5-72.0 - SHALE: Silty and sandy in spots, some cracking upon drying, carbonaceous with little coal at 66.0'-67.0', no to low HCl reaction, core breaks into chunks 1/4" to 1' long.
		90							80			72.0-154.5 - SANDSTONE: Fine to medium grained, very silty 72.0-74.0, core breaks into 1/4" chunks to 10' long core pieces, hardness 3-7, 2" of coal at 79.0', shale layers at 110'-111.5', 148.0'-148.9', and 152.5'-153.5'.
		90										154.5-168.0 - COAL: Subbituminous.
		96							90			168.0-168.9 - SHALE: Carbonaceous, hardness 5, no to low HCl reaction, dark gray.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming SHEET 1 OF 2 HOLE NO. DH-2

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-2 LOCATION COORDS. N. E. GROUND ELEV. 7044± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8/18/75 FINISHED 8/23/75 DEPTH OF OVERBURDEN 2.7' TOTAL DEPTH 168.9' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		80										
	110	97							110, 111.5			
	120	100							120			
		70										
	130	19							130			
	140	79							140			
									148.0, 148.9			
	150	100							150, 152.5, 153.5, 154.5			
	160	80							160, 168.0			
	170		Bottom of Hole 168.9'						170			
	180								180			
	190								190			

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

7-1387 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-4 LOCATION COORDS. N. E. GROUND ELEV. 7100± DIP (ANGLE FROM HORIZ.)

BEGUN FINISHED DEPTH OF OVERBURDEN 19.0' TOTAL DEPTH 158.3' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Porta-drill Model TK truck mounted.	PUSH	100, 100					0.0-19.0 SUPERFICIAL SOIL DEPOSITS
No recovery from 9.3'-19.0'.	FISH TAIL	9					0.0-19.0 -SAND: Fine, silty, contains numerous lime nodules at 4'-8', unconsolidated, hardness 1-3, HCl reaction: 0.0'-9.3' high, 9.3'-19.0' - none to low, gray brown. (SM)
4-1/8" wireline core used from 19.0'-158.3'.						19.0	19.0-158.3 FORT UNION FORMATION
Revert used as drilling fluid.	CORE	40					19.0-39.0 - SANDSTONE: Contains iron cemented and stained zones throughout, 1' shale zone at 21', core pieces .05'-.4', slight carbonate cementation from 33.0'-39.0', hardness 2-4, HCl reaction none to medium, brown with slight gray mottling.
100% water loss from 19.0'-158.3' impossible to stop, used excess revert and also tried cottonseed hulls and shredded paper in drill mud.		100, 20				39.0	39.0-48.5 - SHALE: Upper portion sandy and contains small coal seams (.1'), carbonaceous, core length .1'-.5', disintegrates when wetted, hardness 4-6, no HCl reaction, gray-dark gray.
Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.		62				48.5	48.5-53.3 - SANDSTONE: Thin bedded, well cemented, contains carbon inclusions on bedding planes, core length .2'-1.2', hardness 6-7, no HCl reaction, gray.
		100, 100, 100, 100, 100, 100, 100, 50				53.3	53.3-158.3 - SHALE: Carbonaceous, disintegrates when wetted, core lengths fragmented to 1.8', hardness 4-6, no HCl reaction, coal zones - 76'-77', 125.3'-126.8', 129.5'-141.0', and 142.0'-142.4', gray-dark gray.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming SHEET 1 OF 4 HOLE NO. DH-4

GEOLOGIC LOG OF DRILL HOLE

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-4 LOCATION COORDS. N. E. GROUND ELEV. 7100± DIP (ANGLE FROM HORIZ.) 0

BEGUN FINISHED DEPTH OF OVERBURDEN 19.0' TOTAL DEPTH 158.3' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		65										
		80										
		30										
		100										
		95										
		100										
		100										
		100										
		100										
		75										
		90							158.3			
				B.O.H. 158.3'								

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-5 LOCATION COORDS. N. E. GROUND ELEV. 7200± DIP (ANGLE FROM HORIZ.)

BEGUN 9-9-75 FINISHED 9-15-75 DEPTH OF OVERBURDEN 5.0 TOTAL DEPTH 98.1 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Porta-drill Model TK truck mounted. NX push samples to 17.8'. No recovery. 4-1/8" wireline core from 17.8' to 98.1'. Revert used as drilling fluid.	PUSH	100, 100, 100, 100, 100, 0, 0, 0, 0, 0, 0, 0, 0							8.0			0.0-5.0 SUPERFICIAL SOIL DEPOSITS 0.0-8.0 - SHALE: Silty, iron stained joints, highly weathered to 5.0', hardness 4-5, no HCl reaction, push samples taken (no core), gray. (CL) 5.0-98.1 FORT UNION FORMATION 8.0-77.7 - SANDSTONE: Massive, iron stained and cemented in spots, hardness 3-6, core pieces from .2-2.5' average .5', HCl reaction none to high, gray. 77.7-90.7 - COAL: Small amount shale interbedded. 90.7 - 98.1 - SHALE: Carbonaceous, cracks upon drying, hardness - 5, no HCl reaction, core pieces from fragments to .8', dark gray.
Water Losses 5.0-8.0 75% 8.0-17.8 95% 17.8-42.5 25% 42.5-90.7 40% 90.7-98.1 50%	4⅛" CORE	45, 0, 100, 70, 67, 88, 100, 100, 100, 100							77.7 90.7			
Core vandalized, dumped from boxes from 22.7' to 76.0' Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.			BOH	98.1'								

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-6 LOCATION COORDS. N. E. GROUND ELEV. 7180± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9-22-75 FINISHED 9-27-75 DEPTH OF OVERBURDEN 7.5 TOTAL DEPTH 147.5 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Porta-drill Model TK truck mounted. Push samples from 0.0 to 21.5. 4-1/8" wireline core taken from 21.5 to 137.5. Nx core taken from 137.5 to 147.5. Revert used as drilling fluid. Hole caved from 101.5 to 80.0 overnight. Water Losses 21.5-31.5 20% 52.2-101.5 30% 131.5-147.5 50% Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.	PUSH (0-21.5) 4-1/8" CORE (21.5-)	100 100 100 90 100 100 98 69 45 96 98 99 99 70							7.5 12.5 48.1			0.0-7.5 SUPERFICIAL SOIL DEPOSITS 0.0-7.5 - CLAY AND SILT: Slightly sandy, hardness 1-4, HCl reaction low to high, push samples taken (no core), gray. (CL) 7.5-147.5 FORT UNION FORMATION 7.5-12.5 - COAL: Shaley, powdery, highly weathered, sandy, dark brown. 12.5-48.1 - SHALE: Carbonaceous, slightly weathered to highly weathered iron stained joints from 27.0-28.5, coal from 24.5-25.0, 32.0-36.0, and 42.0-44.1, highly carbonaceous 21.5-26.5, core pieces, 1/8"-1' pieces, cracks upon drying, core completely disintegrated to 21.5 and highly broken to 28.4, core pieces below 28.4 from .1' to 1.0' average .35', HCl reaction - none to low, gray to black color depending on amount of organic carbon. 48.1-111.5 - SANDSTONE: Silty, HCl reaction - none to high, core pieces range from fragments to 1.5', average .2', color gray to yellow depending on cement. Depth / Hardness 48.1-54.0 / 4 to 5 54.0-101.5 / 3 to 4 101.5-111.5 / 4 to 6 Depth / Cementation 48.1-52.0 / Clay 52.0-54.0 / $CaCO_3$ 93.0-101.5 / " 108.5-111.5 / " 54.0-55.0 / Iron 101.5-103.5 / "

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-6 LOCATION COORDS. N. E. GROUND ELEV 7180+ DIP (ANGLE FROM HORIZ) Vertical

BEGUN 9-22-75 FINISHED 9-27-75 DEPTH OF OVERBURDEN 7.5 TOTAL DEPTH 147.5 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Mike Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		30										111.5-147.5 - SHALE: Carbonaceous, cracks upon drying, shows slicks, hardness 4-6, no HCl reaction, highly carbonaceous 122.0-124.0 and 138.0-139.0, core pieces range from fragments to .5' average .2', dark gray to black color, 1.0 coal seam from 137.0 to 138.0.
		99							111.5			
		65										
		67										
	NX CORE	85										
				B.O.H.-	147.5'							

Depth scale: 110, 120, 130, 140, 150, 160, 170, 180, 190

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming SHEET 2 OF 2 HOLE NO. DH-6

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Red Rim Site   PROJECT EMRIA-BLM   STATE Wyoming

HOLE NO. DH-7   LOCATION   COORDS. N.   E.   GROUND ELEV. 6925±   DIP (ANGLE FROM HORIZ.)

BEGUN 9-17-75   FINISHED 9-19-75   DEPTH OF OVERBURDEN 19.5'   TOTAL DEPTH 80.0'   BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED   LOGGED BY Mike Walker   LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE / DOUBTFUL / UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Porta-drill Model TK truck mounted.	PUSH (0–19.5)	100								0.0-19.5 SUPERFICIAL SOIL DEPOSITS
Push sampled to 19.5'.		50								19.5-80.0 FORT UNION FORMATION
Cored with 4-1/8" wireline core from 19.5' to 80.0'.		0								0.0-30.0 - SAND: Fine, silty, unconsolidated to 19.5', limy nodules in upper 7.0', HCl reaction - high, hardness 19.5-30.0 - 3 to 5, thin bands (spider webbing) of limy cement from 27.1-30.0, gray. (SM)
Revert used as drilling fluid.		0					19.5			30.0-32.0 - COAL, SAND, AND SILT: Some clay, all highly carbonaceous, hardness 5, some iron staining and limy "spider webbing", HCl reaction - medium to high, dark gray to black.
80' of plastic well screen set in hole upon completion.	CORE (19.5–80)	91					32.0			32.0-35.6 - SHALE: Top 2' limy, remainder carbonaceous, hardness 5-6, HCl reaction low to medium, shows slicks, gray to dark gray.
Water Losses		100					35.6			35.6-45.9 - COAL
19.5-30.0 10%		87								45.9-47.9 - SHALE: Carbonaceous, hardness 5, shows slicks, black.
34.7-50.0 30%		94					45.9			47.9-80.0 - SANDSTONE: Silty, hardness 3-5, HCl reaction low to high, $CaCO_3$ cement (very hard) from 73.0-76.0, 1/2" thick carbonaceous band inclined 60° at 57', bedding apparent at 57.4' is 13°, core pieces from .2' to 2.0' average .5', gray.
50.0-54.0 75%		90					47.9			
54.0-55.0 100%		100								
55.0-80.0 75%		93								
Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming		94								
		97	B.O.H. -	80.0'			80			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site   PROJECT EMRIA-BLM   STATE Wyoming   SHEET 1 OF 1   HOLE NO. DH-7

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GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming
HOLE NO. DH-8 LOCATION COORDS. N. E. GROUND ELEV 6925+ DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 6-2-75 FINISHED 6-18-75 DEPTH OF OVERBURDEN 48' TOTAL DEPTH 190.5 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Bennett, Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P. Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

Drilled with Damco 1250 truck-mounted drill rig.

2" diameter push samples 0-29.0. 4-1/8" diameter core 29.0-160.7.

Overshot and spear of 4-1/8" wireline core barrel broke. Necessary to reduce to 2" core 160.7-185.0.

Poor core recovery due to friability of sandstone and weight and slickness of claystone.

Water Losses

21.0'-39.0'	30%
39.0'-49.0'	75%
49.0'-59.0'	20%
59.0'-79.0'	10%
79.0-89.0'	0%
89.0'-95.0'	10%
95.0-115.0'	0%
115.0'-155.6'	10%
155.6'-170.7'	40%

Hole caved when left overnight.

170' of 4" plastic pipe set in hole for ground water studies.

Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.

Type and size of hole: PUSH (0-29); 4 1/8" CORE

Core recovery (%): 31, 0, 100, 54, 39, 51, 91, 7, 57, 98

0-48.0 Superficial Soil Deposits

0-37.6 Clay - Moderately to highly plastic. Scattered sandy and gravelly zones. Hardness 3-4. Moist to wet. Gray and brown. Core lost 29-32.7. Driller reports it as bentonite. Core on each side of lost interval stains blue using benzidine stain test; this is an indication of bentonitic soils. Non- to moderately calcitic (CH).

37.6-48.0 Sand - Fine-grained, rounded, quartz grains with mica flakes. Few non-plastic fines. Very slightly cemented. Hardness 1-2. Moist to damp. Brown to light gray. May be broken down formation rock (SP).

48-200 FT. UNION FORMATION

48.0-79.4 Sandstone - Fine-grained, rounded quartz grains with scattered mica flakes. Moderately to highly calcitic. Friable. Clay pods, 1/2-inch in diameter, increase last 2 feet. Hardness 6, 49-59 ft., otherwise 2-3. Moist. Gray.

79.4-91.8 Most of core lost but appears to be claystone with very hard quartzitic layers and pods. Carbonaceous with 2-inch coal seam 89-91.8. Greenish.

91.8-114.6 Sandstone - Fine-grained, rounded quartz grains with mica flakes. Medium grained with clay and coal pods 91.8-95. Carbonaceous banding 96.4-102.5 dipping 14°. Very hard claystone 102.3-102.5. Very slightly calcitic. Poorly cemented. Friable. Hardness 4. Breaks through sandstone along 14° dipping planes. Gray sandstone, brown claystone.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming SHEET 1 OF 2 HOLE NO. DH-8

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

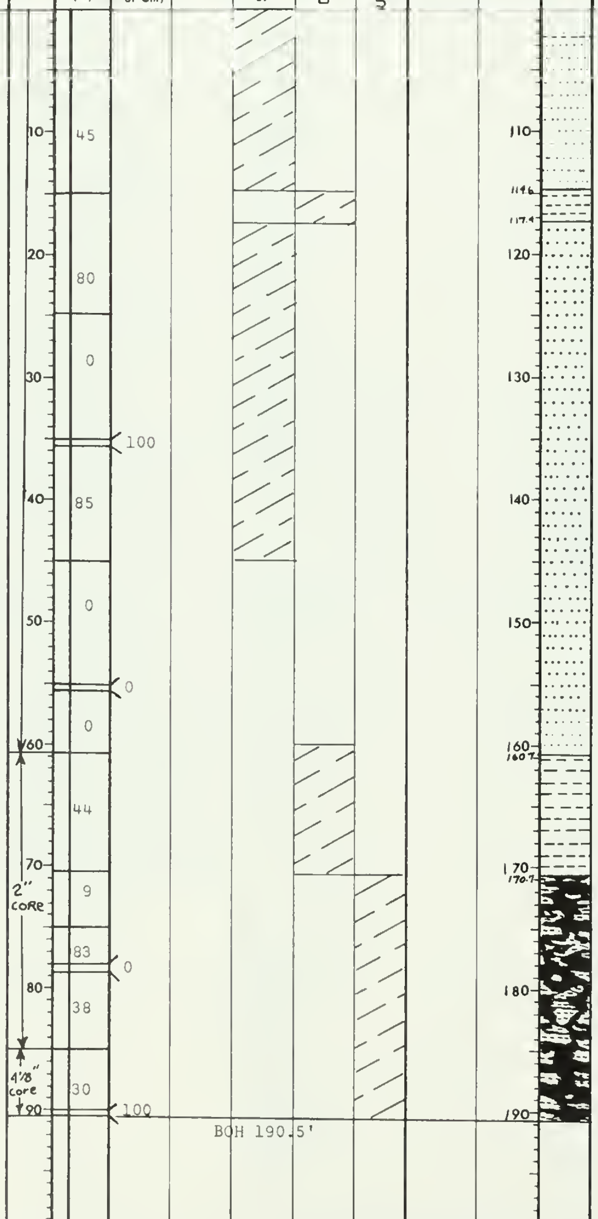
FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-8 LOCATION ... COORDS. N. ... E. ... GROUND ELEV. 6925± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6-2-75 FINISHED 6-18-75 DEPTH OF OVERBURDEN 48' TOTAL DEPTH 190.5 BEARING ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED ... LOGGED BY Bennett, Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION



114.6-117.4 Claystone - Moderately calcitic near 114.6, otherwise none. Hardness 5. Desiccation cracks form on core surface as it dries. Gray.

117.4-160.7 Sandstone - Fine-grained, some medium. Rounded quartz grains with mica flakes. Non- to moderately calcitic. Scattered carbonaceous banding, especially 139.4-142.0. Friable. Hardness 4.

160.7-170.7 Claystone - Dark gray, carbonaecous, no HCL reaction, hardness 5.

170.7-190.5 Claystone & Coal - Claystone same as above, coal subbituminous.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . . O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming SHEET 2 OF 2 HOLE NO. DH-8

-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Red Rim Site — PROJECT: EMRIA-BLM — STATE: Wyoming

HOLE NO.: DH-9 — LOCATION — COORDS. N. ... E. ... — GROUND ELEV.: 7085± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6-19-75 — FINISHED: 8-7-75 — DEPTH OF OVERBURDEN: 26' — TOTAL DEPTH: 180.2 — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: ... — LOGGED BY: J. M. Walker — LOG REVIEWED BY: N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Portadrill Model TK.	4 1/8 core					0-26 SUPERFICIAL SOIL DEPOSITS
4-1/8" diameter core-revert used as drilling fluid.		0				0.0-26.0 FINE SAND & SILT: Light gray, unconsolidated. (S M)
Water Losses						26.0-180.2 FORT UNION FORMATION
30.0-35.0' 20%					26.0	26.0-28.0 SANDSTONE: Light gray, h-5 contains very thin carbonaceous layers, breaks very hard along bedding planes.
35.0-52.7 25%					28.0	28.0-31.5 SHALE: Silty, yellow and gray, h-3-5 contains carbonaceous partings.
52.7-80.2 30%		100			31.5	31.5-35.0 SAND: Fine, unconsolidated, scattered small limonite and carbonate nodules. Salt and pepper appearance (tan with dark accessory minerals).
80.2-90.2 40%			100		35.0	35.0-35.5 SANDSTONE: Contains carbonaceous partings, gray, 5 hardness.
90.2-100.2 25%					35.5	35.5-37.5 CLAYSTONE: 2-inch coal seam at 37.0', 3-5 hardness, dark brown.
100.2-180.2 30%		76			37.5	37.5-46.0 SILTSTONE: Grading to sandstone micaceous, 3 hardness, gray with some black banding.
Lost sample from 41.3-45.0'.		100			46.0	46.0-53.7 SHALE: Becoming more carbonaceous until coal hit. Hardness 3-5. 3-inch layer of siltstone at 49.5.
Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.		51			53.7	53.7-57.5 COAL: Subbituminous.
		92			57.5	57.5-65.8 SHALE: Contains carbonaceous particles. Light gray. Hardness 3-5.
		95			65.8	65.8-67.3 SANDSTONE: Micaceous, dark gray with black banding (organic matter). Hardness 3-5.
		98			67.3	67.3-82.2 SHALE: Carbonate seams at 71.5'. Hardness 3-5. Medium to dark gray. HCL React.-Med.
					82.2	82.2-85.7 COAL: Subbituminous.
		99			85.7	85.7-94.0 SILTSTONE: Clayey throughout, few thin bands of carbonaceous shale and fine sandstone. Hardness 5-7. Light gray. HCL React. - Low.
		88			94.0	94.0-105.0 SHALE: Carbonaceous, hardness 4-6. Medium to dark gray. HCL React. - Low - None.

Suitability of overburden columns: SUITABLE, DOUBTFUL, UNSUITABLE. Other columns: ELEVATION (FEET), GRAPHIC LOG, SAMPLES FOR TESTING.

EXPLANATION

CORE LOSS — CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Red Rim Site — PROJECT: EMRIA-BLM — STATE: Wyoming — SHEET 1 OF 2 — HOLE NO. DH-9

GEOLOGIC LOG OF DRILL HOLE

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-9 LOCATION COORDS. N. E. GROUND ELEV 7085± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6-19-75 FINISHED 8-7-75 DEPTH OF OVERBURDEN 26' TOTAL DEPTH 180.2 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY J.M. Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
									105.0			105.0-118.7 SILTSTONE: Sandy and clayey in spots, carbonaceous at bottom. Hardness 5-7. Light to medium gray. HCL React.-Med.-High.
	110	65							110			118.7-120.9 COAL: Subbituminous.
	120	80							118.7 / 120 / 120.9			120.9-127.6 SHALE: Highly carbonaceous. 2-3" coal seams at approximately 123.0' dark gray-black. HCL React.-None-Low.
	130	100							127.6 / 128.1 / 130			127.6-128.1 COAL: Subbituminous.
		100										128.1-150.0 SILTSTONE: Sandy and clayey in spots. Top 1.1' friable and hardness 3. Bottom 20.0', hardness 5-7. Light gray. HCL React.-None-Low.
	140	97							140			150.0-180.2 SANDSTONE: Micaceous and dark minerals throughout. Hardness 5. Light-dark gray. HCL React. 147.0-170.0 Med., 170.0-180.2 None-low.
	150	71							150			
	160	85							160			
	170	35							170			
	180		B.O.H. 180.2'						180			
	190								90			

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

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GEOLOGIC LOG OF DRILL HOLE

SHEET. 1 OF. 2

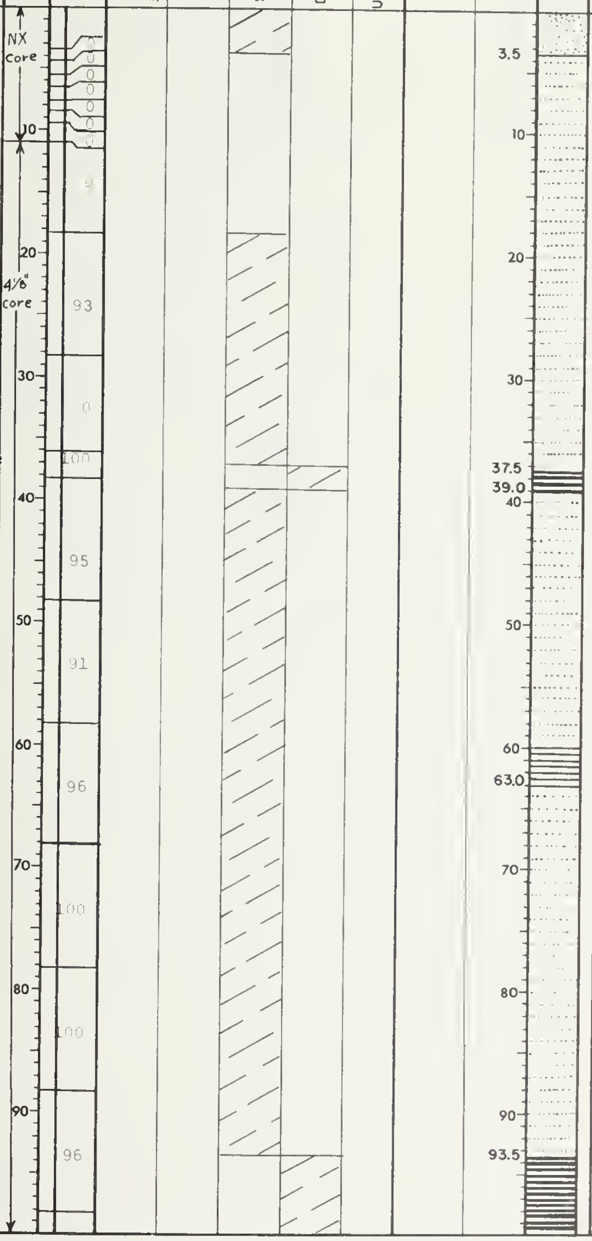
FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-10 LOCATION COORDS. N. E. GROUND ELEV. 7120± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8/8/75 FINISHED 8/15/75 DEPTH OF OVERBURDEN 3.5' TOTAL DEPTH 198.3 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY J. M. Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Damco 250 truck-mounted drill rig using 4-1/8" wireline core.	NX Core (0–11)	0, 0, 0, 0, 0, 0, 0, 0							3.5			0.0-3.5 - SAND: Silty, fine, gray-brown, unconsolidated, numerous dark minerals (Sm).
Water Losses	4 1/8" core	93							10			3.5-198.3 FT. UNION FM.
8.3-98.3 20%		0							20			3.5-37.5 - SANDSTONE: Slightly silty, numerous dark minerals, hardness - 3, last 3' contains organic material - no HCl reaction.
98.3-158.3 30%		100							30			37.5-39.0 - SHALE: Carbonaceous, last 1' brecciated into brown sandstone, hardness 3-5, dark gray, no HCl reaction.
158.3-178.3 30-40%		95							37.5			39.0-60.0 - SANDSTONE: Clayey and silty in spots, contains numerous dark minerals, several claystone conglomerate zones at approximately 57', crossbedded at approximately 42'-45', hardness 3, no to medium HCl reaction.
178.3-188.3 75%		91							39.0			60.0-63.0 - SHALE: Silty, gray, hardness 5.
188.3-198.3 90%		96							40			63.0-93.5 - SANDSTONE: Very fine grained, silty, clayey in spots, hardness 3-5, dark gray.
Hole drilled with Nx 0.0-11.0'. No recovery. Remainder of hole drilled with 4-1/8" wireline.		100							50			93.5-110.0 - SHALE: Carbonaceous, shows slicks, cracks upon drying, hardness 4-6, dark gray.
Elevation estimated from USGS Quadrangle Sheet, Riner, Wyoming.		100							60			
		96							63.0			
									70			
									80			
									90			
									93.5			



EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming SHEET 1 OF 2 HOLE NO. DH-10

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Red Rim Site PROJECT EMRIA-BLM STATE Wyoming

HOLE NO. DH-10 LOCATION COORDS. N. E. GROUND ELEV. 7120+ DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 8/8/75 FINISHED 8/15/75 DEPTH OF OVERBURDEN 3.5' TOTAL DEPTH 198.3' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY J. M. Walker LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100			Doubtful					110.0-117.8 - SILTSTONE: Clayey grading to sandy, gray, hardness 4-5.
	110	82			Suitable		110			117.8-133.9 - SANDSTONE: Very fine grained, silty, hardness 4-5, gray with some black carbonaceous streaking.
	120	100			Suitable		117.8, 120			133.9-134.5 - COAL: Subbituminous.
	130	78			Suitable		130, 133.9, 134.5			134.5-143.5 - SHALE: Carbonaceous, upper portion contains coal streaks, hardness 3-6, dark gray.
	140	92			Doubtful		140, 143.5			143.5-198.3 - SANDSTONE: Fine grained, some calcite banding and iron staining in upper 1', tan to 154.0, brown with numerous dark minerals 154.0-171.0, gray from 171.0-174.0, brown from 174.0-198.3, clayey from 158.3-159.2.
	150	95			Doubtful		150			
	160	88			Doubtful		160			
	170	84			Doubtful		170			
	180	79			Doubtful		180			
	190	70			Doubtful		190, 198.3			
			BOH - 198.3							

Depth	Hardness
143.5-145.5	5-6
145.5-150.0	2-4
150.0-154.0	5-6
154.0-171.0	3-4
171.0-174.0	5-6
174.0-198.3	3-4

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

APPENDIX B

COAL

Table B1.--U.S.G.S. sample number, bed name, hole number and depth interval of core coal samples, Red Rim study area, Carbon and Sweetwater Counties, Wyo.

U.S.G.S. Sample no.	Bed	Hole no.	Depth interval (feet)
D178449	D_1	1	81.3- 87.7
D178450	E zone	9	53.7- 57.7
D178451	--do--	--do--	82.2- 85.7
D178452	F_2	4	125.3-126.8
D178453	--do--	--do--	129.5-130.5
D178454	--do--	--do--	130.7-135.9
D178455	--do--	--do--	135.9-141.0
D178456	E zone	2	39.2- 41.0
D178457	--do--	--do--	37.9- 38.9
D178458	--do--	--do--	36.3- 37.9
D178459	--do--	--do--	41.7- 43.9
D178460	F_1	--do--	164.7-167.0
D178461	--do--	--do--	158.0-163.3
D178462	--do--	--do--	154.0-158.0
D178463	--do--	--do--	151.0-154.0
D178464	F_2	5	83.4- 88.8
D178463	--do--	--do--	77.8- 82.9
D178466	G zone	6	24.0- 25.2
D178467	--do--	--do--	31.5- 36.0
D178468	--do--	--do--	42.0- 44.1
D178469	H zone	--do--	137.0-138.5
D178470	F_2	7	35.6- 39.6
D178471	--do--	--do--	40.2- 45.2

Table B2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 23 samples, Red Rim study area, Carbon and Sweetwater Counties, Wyo.

[All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: 1, as received; 2, moisture free; 3. moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.

		Proximate analysis				Ultimate analysis				
Sample	Form of analysis	Moisture	Vol.Mtr.	Fixed C	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
D178449	1	26.1	23.8	32.7	17.4	5.7	43.0	0.6	32.7	0.6
	2	-	32.2	44.2	23.5	3.8	58.2	.8	12.9	.8
	3	-	42 1	57.9	-	5.0	76.1	1.1	16.8	1.1
D178450	1	24.5	29.2	39.1	7.2	5.6	50.4	.7	35.3	.8
	2	-	38.7	51.8	9.5	3.8	66.8	.9	17.9	1.1
	3	-	42.8	57.2	-	4.2	73.8	1.0	19.8	1.2
D178451	1	23.5	26.5	31.9	18.1	5.1	42.0	.7	32.4	1.7
	2	-	34.6	41.7	23.7	3.3	54.9	.9	15.0	2.2
	3	-	45.4	54.6	-	4.3	71.9	1 2	19.7	2.9
D178452	1	25.8	34.0	34 1	6.1	6.4	51.0	.6	35.2	.7
	2	-	45.8	46.0	8.2	4.8	68.7	.8	16.5	.9
	3	-	49.9	50.1	-	5.2	74.9	.9	18.0	1.0
D178453	1	24.5	28.2	39.6	7 7	5.7	50.9	.7	34.7	.3
	2	-	37.4	52.5	10.2	3.9	67.4	.9	17.1	.4
	3	-	41.6	58.4	-	4.4	75.1	1.0	19.1	.4
D178454	1	23.2	29.6	40.1	7.1	5.7	51.6	.5	34.8	.3
	2	-	38.5	52.2	9.2	4.1	67.2	.7	18.5	.4
	3	-	42.5	57.5	-	4.5	74.0	.7	20.3	.4
D178455	1	22.4	29.3	37.1	11.2	5.6	48.8	.5	33.3	.6
	2	-	37.8	47.8	14.4	4.0	62.9	.6	17.3	.8
	3	-	44.1	55.9	-	4.7	73.5	.8	20.2	.9
D178456	1	26.2	27.3	40.3	6.2	6.0	50.3	.9	35.5	1.1
	2	-	37.0	54.6	8.4	4.2	68.2	1.2	16.5	1.5
	3	-	40.4	59.6	-	4.6	74.4	1.3	18.1	1.6
D178457	1	25.1	27.7	39.2	8.0	5.9	49.1	.7	34.6	1.7
	2	-	37.0	52.3	10.7	4.2	65.6	.9	16.4	2.3
	3	-	41.4	58.6	-	4.7	73.4	1.0	18.4	2.5
D178458	1	17.8	18.1	19.6	44.5	3.8	25.2	.3	24.7	1.5
	2	-	22.0	23.8	54.1	2.2	30.7	.4	10.8	1.8
	3	-	48.0	52.0	-	4.8	66.8	.8	23.5	4.0
D178459	1	17.9	29.0	36.8	16.3	5.0	48.3	.7	28.8	.9
	2	-	35.3	44.8	19.9	3.7	58.8	.9	15.7	1.1
	3	-	44.1	55.9	-	4.6	73.4	1.1	19.6	1.4
D178460	1	26.5	23.7	36.7	13.1	5.5	44.5	.6	35.3	1.0
	2	-	32.2	49.9	17.8	3.5	60.5	.8	16.0	1.4
	3	-	39.2	60.8	-	4.2	73.7	1.0	19.4	1.7

Table B2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 23 samples, Red Rim study area, Carbon and Sweetwater Counties, Wyo.--Continued

Sample	Form of analysis	Btu	A.d.loss	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic
D178449	1	7220	9.2	0.02	0.05	0.55
	2	9770	-	.03	.07	.74
	3	12780	-	.04	.09	.97
D178450	1	8420	6.8	.02	.42	.37
	2	11150	-	.03	.56	.49
	3	12330	-	.03	.61	.54
D178451	1	7110	5.1	.02	.33	1.39
	2	9290	-	.03	.43	1.82
	3	12170	-	.03	.57	2.38
D178452	1	8750	6.1	.07	.13	.51
	2	11790	-	.09	.18	.69
	3	12850	-	.10	.19	.75
D178453	1	8540	5.8	.02	.13	.18
	2	11310	-	.03	.17	.24
	3	12600	-	.03	.19	.27
D178454	1	8590	4.3	.02	.06	.21
	2	11180	-	.03	.08	.27
	3	12320	-	.03	.09	.30
D178455	1	8220	5.1	.02	.06	.53
	2	10590	-	.03	.08	.68
	3	12380	-	.03	.09	.80
D178456	1	8510	7.4	.02	.05	1.05
	2	11530	-	.03	.07	1.42
	3	12590	-	.03	.07	1.55
D178457	1	8300	5.7	.02	.08	1.55
	2	11080	-	.03	.11	2.07
	3	12410	-	.03	.12	2.32
D178458	1	4330	6.6	.06	.52	.88
	2	5270	-	.07	.63	1.07
	3	11490	-	.16	1.38	2.33
D178459	1	8140	1.7	.09	.06	.75
	2	9910	-	.11	.07	.91
	3	12370	-	.14	.09	1.14
D178460	1	7460	7.4	.05	.05	.86
	2	10150	-	.07	.07	1.17
	3	12350	-	.08	.08	1.42

Table B2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 23 samples, Red Rim study area, Carbon and Sweetwater Counties, Wyo.--Continued

Sample	Form of analysis	Btu	A.d.loss	Forms of sulfur Sulfate	Pyritic	Organic
D178461	1	8620	5.1	0.07	0.13	0.51
	2	11270	-	.09	.17	.67
	3	12600	-	.10	.19	.75
D178462	1	6790	6.9	.04	.07	.71
	2	8620	-	.05	.09	.90
	3	12280	-	.07	.13	1.28
D178463	1	8250	3.6	.06	.03	1.11
	2	10700	-	.08	.04	1.44
	3	12480	-	.09	.05	1.68
D178464	1	8430	7.1	.02	.07	.56
	2	10980	-	.03	.09	.73
	3	12270	-	.03	.10	.82
D178465	1	8280	7.9	.02	.08	.31
	2	11000	-	.03	.11	.41
	3	12320	-	.03	.12	.46
D178466	1	2370	10.9	.54	.15	.24
	2	3000	-	.68	.19	.30
	3	8650	-	1.97	.55	.88
D178467	1	7160	14.8	.02	.02	.85
	2	10230	-	.03	.03	1.21
	3	12470	-	.03	.03	1.48
D178468	1	7910	7.1	.03	.10	1.12
	2	10370	-	.04	.13	1.47
	3	12440	-	.05	.16	1.76
D178469	1	6480	14.1	.04	.02	.33
	2	9220	-	.06	.03	.47
	3	12390	-	.08	.04	.63
D178470	1	4840	24.5	.10	.01	.18
	2	8550	-	.18	.02	.32
	3	9980	-	.21	.02	.37
D178471	1	7590	6.9	.02	.02	.37
	2	10200	-	.03	.03	.50
	3	12120	-	.03	.03	.59

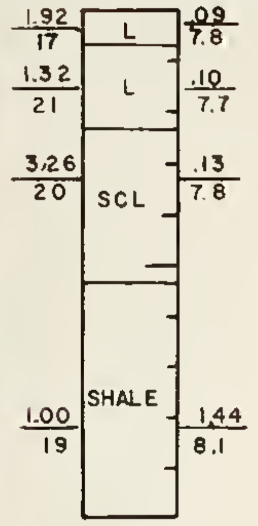
Table B2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 23 samples, Red Rim study area, Carbon and Sweetwater Counties, Wyo.--Continued

		Proximate analysis				Ultimate analysis				
Sample	Form of analysis	Moisture	Vol.Mtr.	Fixed C	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
D178461	1	23.5	28.8	39.6	8.1	6.0	51.6	0.6	33.0	0.7
	2	-	37.6	51.8	10.6	4.4	67.5	.8	15.8	.9
	3	-	42.1	57.9	-	5.0	75.4	.9	17.7	1.0
D178462	1	21.2	23.7	31.6	23.5	5.1	41.0	.5	29.1	.8
	2	-	30.1	40.1	29.8	3.5	52.0	.6	13.0	1.0
	3	-	42.9	57.1	-	5.0	74.1	.9	18.5	1.4
D178463	1	22.9	27.6	38.5	11.0	5.8	49.2	.8	32.0	1.2
	2	-	35.8	49.9	14.3	4.2	63.8	1.0	15.1	1.6
	3	-	41.8	58.2	-	4.9	74.4	1.2	17.6	1.8
D178464	1	23.2	29.8	38.9	8.1	5.9	50.4	.6	34.3	.7
	2	-	38.8	50.7	10.5	4.3	65.6	.8	17.8	.9
	3	-	43.4	56.6	-	4.8	73.4	.9	19.9	1.0
D178465	1	24.7	27.5	39.7	8.1	6.0	49.9	.7	34.9	.4
	2	-	36.5	52.7	10.8	4.3	66.3	.9	17.2	.5
	3	-	40.9	59.1	-	4.8	74.3	1.0	19.3	.6
D178466	1	21.0	18.1	9.3	51.6	3.8	16.4	.3	27.0	.9
	2	-	22.9	11.8	65.3	1.9	20.8	.4	10.5	1.1
	3	-	66.1	33.9	-	5.4	59.9	1.1	30.4	3.3
D178467	1	30.0	24.2	33.2	12.6	6.3	42.5	.6	37.1	.9
	2	-	34.6	47.4	18.0	4.2	60.7	.9	14.9	1.3
	3	-	42.2	57.8	-	5.2	74.0	1.0	18.2	1.6
D178468	1	23.7	26.5	37.1	12.7	5.7	47.2	.6	32.6	1.2
	2	-	34.7	48.6	16.6	4.0	61.9	.8	15.1	1.6
	3	-	41.7	58.3	-	4.8	74.2	.9	18.1	1.9
D178469	1	29.7	21.6	30.7	18.0	5.9	39.0	.5	36.2	.4
	2	-	30.7	43.7	25.6	3.7	55.5	.7	13.9	.6
	3	-	41.3	58.7	-	5.0	74.6	1.0	18.7	.8
D178470	1	43.4	24.0	24.5	8.1	6.6	32.1	.5	52.4	.3
	2	-	42.4	43.3	14.3	3.1	56.7	.9	24.4	.5
	3	-	49.5	50.5	-	3.7	66.2	1.0	28.5	.6
D178471	1	25.6	25.8	36.8	11.8	5.9	45.6	.5	35.8	.4
	2	-	34.7	49.5	15.9	4.1	61.3	.7	17.5	.5
	3	-	41.2	58.8	-	4.9	72.8	.8	20.8	.6

APPENDIX C

SOIL

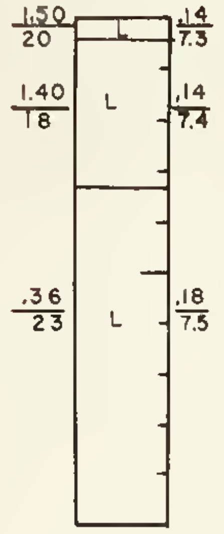
NO. 18-1



LOCATION: 300' SOUTH 500' WEST OF SE CORNER OF $SE\frac{1}{4}\ NW\frac{1}{4}$

PM: CALCAROUS SOFT SHALE AND SILTSTONE

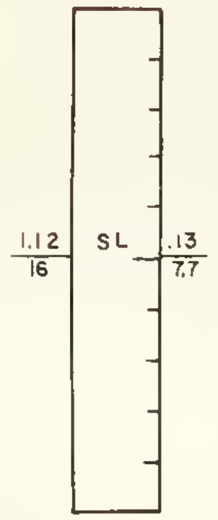
NO. 18-4



LOCATION: 600' SOUTH 250' WEST OF NE CORNER OF $NW\frac{1}{4}\ SE\frac{1}{4}$

PM: VALLEY FILL

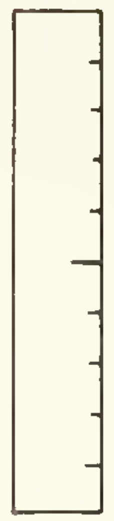
NO. DH-9



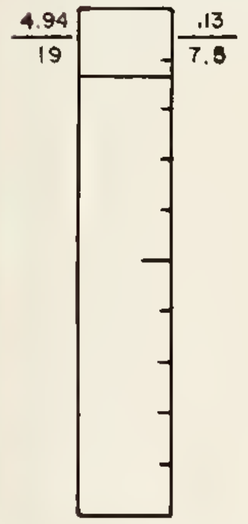
LOCATION: 200' NORTH 400' EAST OF SW CORNER OF $NW\frac{1}{4}\ NE\frac{1}{4}$

PM: SOFT WEATHERED SANDY SHALE

NO.



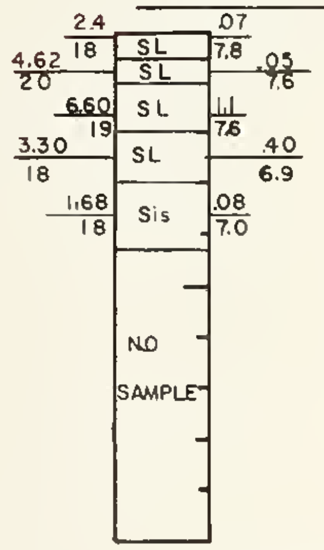
NO. 18-2



LOCATION: 180' NORTH 450' EAST OF SW CORNER OF $SW\frac{1}{4}\ SW\frac{1}{4}$

PM: SANDSTONE

NO. 18-5

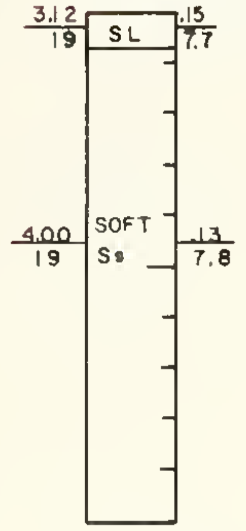


LOCATION: 50' NORTH 500' EAST OF SW CORNER OF $NE\frac{1}{4}\ NE\frac{1}{4}$

PM: SOFT SANDSTONE

REMARKS: ROUGH AND BROKEN TOPOGRAPHY GENERALLY EXCEEDS 25% SLOPE

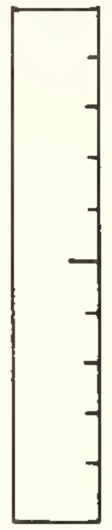
NO. DH-10



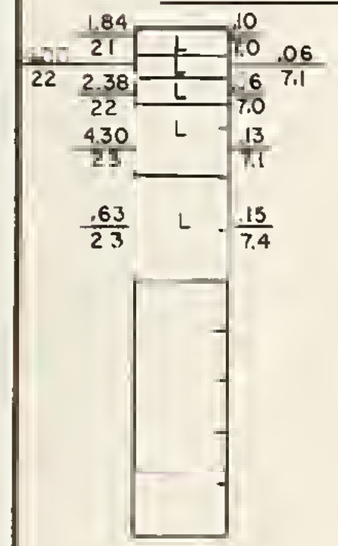
LOCATION: 600' SOUTH 500' WEST OF NE CORNER OF $SE\frac{1}{4}\ SE\frac{1}{4}$

PM: MIXED SANDSTONE AND SHALE

NO.



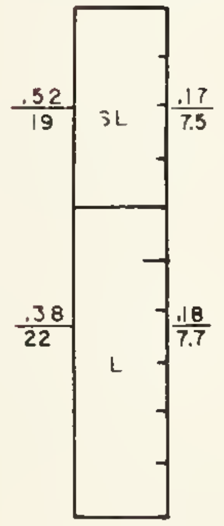
NO. 18-3



LOCATION: 300' NORTH 50' EAST OF SW CORNER OF $SE\frac{1}{4}\ SW\frac{1}{4}$

PM: SANDSTONE

NO. DH-8

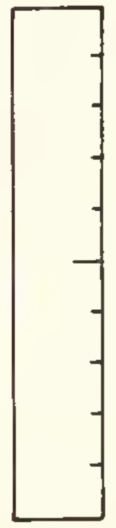


LOCATION: 300' SOUTH 250' WEST OF NE CORNER OF $NE\frac{1}{4}\ NE\frac{1}{4}$

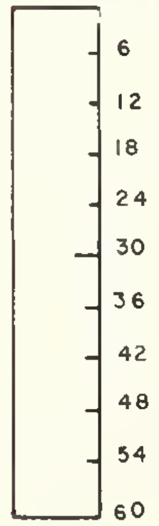
PM: VALLEY FILL

REMARKS: SOIL AGGREGATION POORLY DEFINED

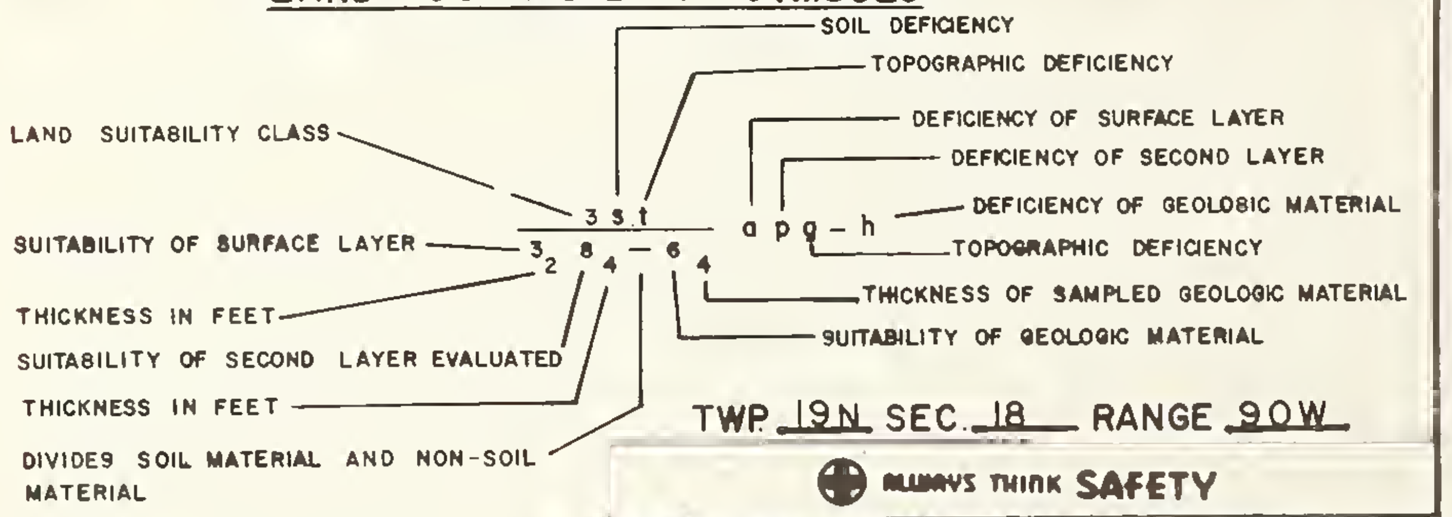
NO.



NO. DEPTH IN INCHES

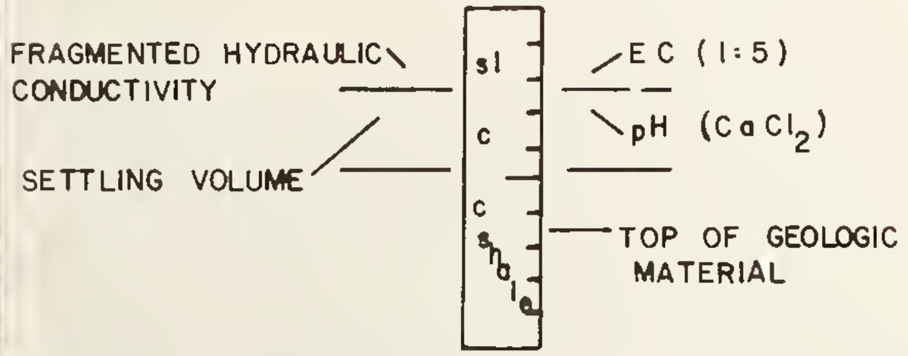


LAND SUITABILITY SYMBOLS



TWP. 19N SEC. 18 RANGE 90W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

- s SALINITY
- a SODICITY
- w WEATHERABILITY
- k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
- b SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
- v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

SCALE: 1" = 1000'

RED RIM STUDY AREA – WYOMING

ALWAYS THINK SAFETY

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

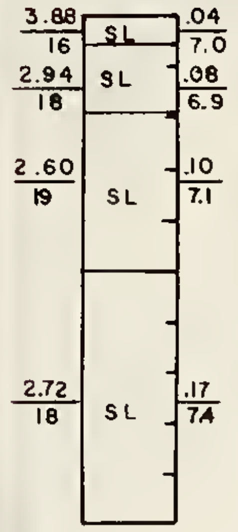
LAND SUITABILITY

LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED W C LAUBNER SUBMITTED
DRAWN W C LAUBNER RECOMMENDED
CHECKED T CAPPELLUCCI APPROVED

L M REGION, DEN., COLO. FIGURE C1

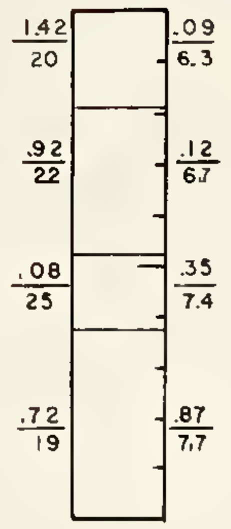
NO. 8-1



LOCATION: 300' NORTH 350' SOUTH OF SE CORNER OF SE$\frac{1}{4}$ NE$\frac{1}{4}$

PM: AEOLIAN DEPOSITION

NO. DH-7

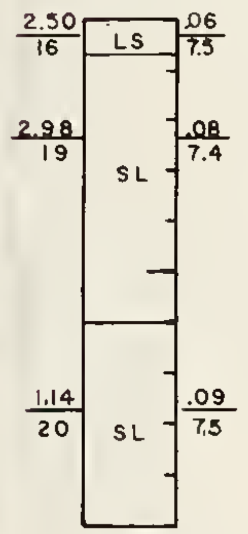


LOCATION: 200' NORTH 250' WEST OF SE CORNER OF SE$\frac{1}{4}$ NW$\frac{1}{4}$

NO.

NO.

NO. 8-2



LOCATION: 400' SOUTH 200' EAST OF NW CORNER OF NE$\frac{1}{4}$ SE$\frac{1}{4}$

PM: ALLUVIUM

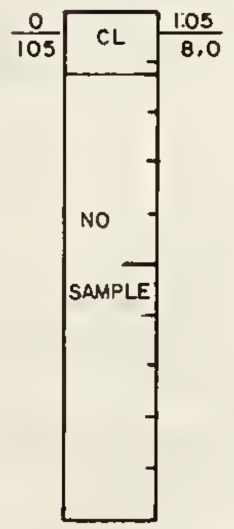
REMARKS: COARSER TEXTURED THAN MOST OF SURROUNDING AREA

NO.

NO.

NO.

NO. 8-3



LOCATION: 500' SOUTH 450' EAST OF NW CORNER OF SE$\frac{1}{4}$ SE$\frac{1}{4}$

PM: ALLUVIUM

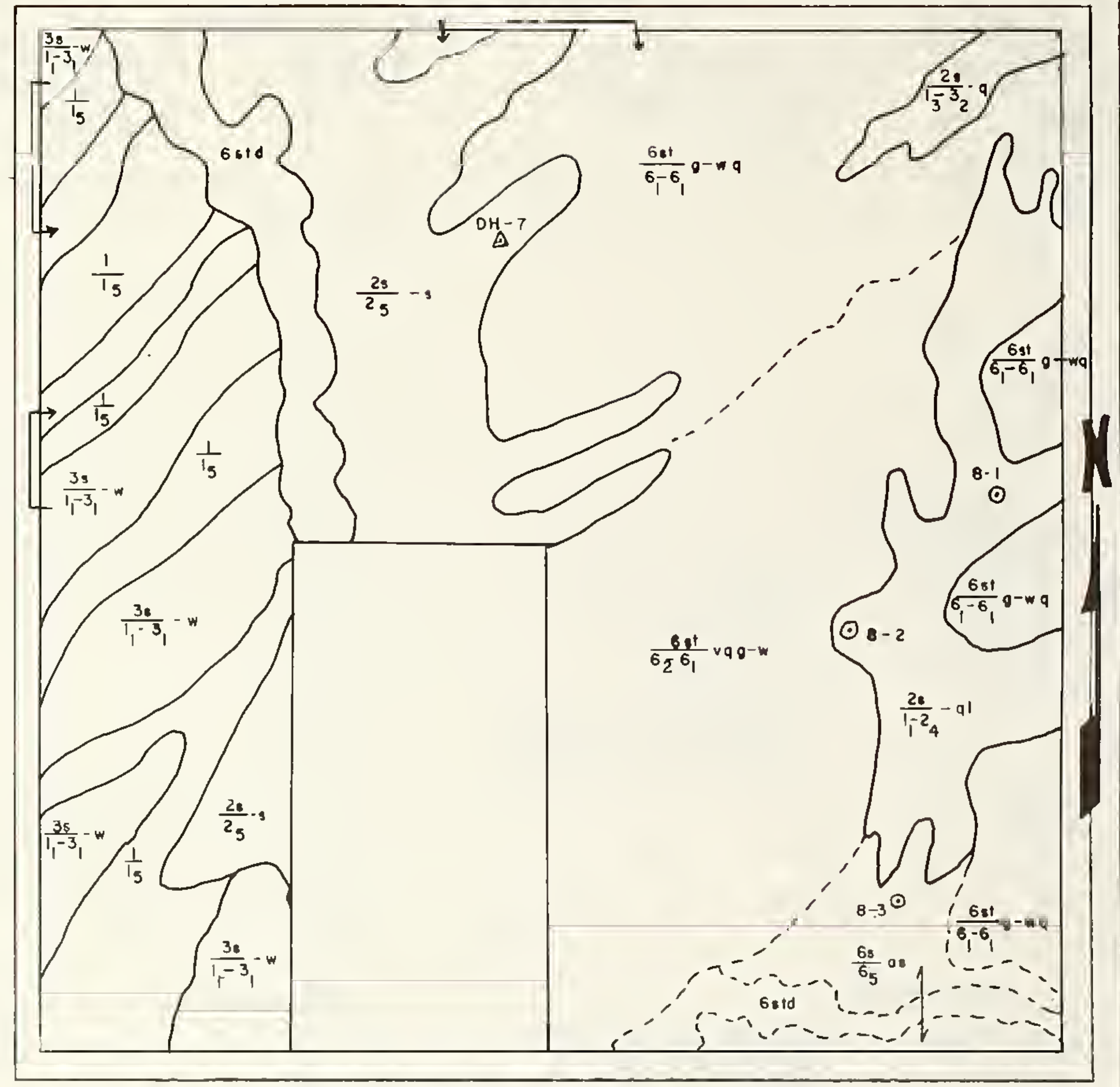
REMARKS: VISUAL OBSERVATION OF EXISTING VEGETATION AND SOIL CONDITION PRECLUDE FURTHER SAMPLING

NO.

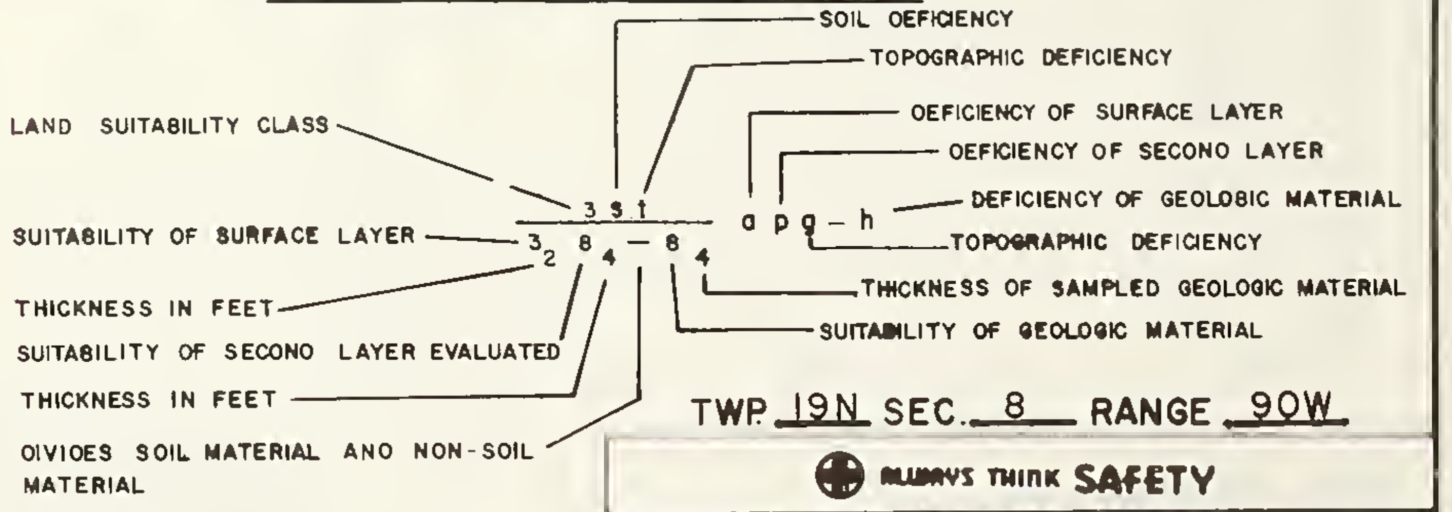
NO.

NO. DEPTH IN INCHES

6
12
18
24
30
36
42
48
54
60

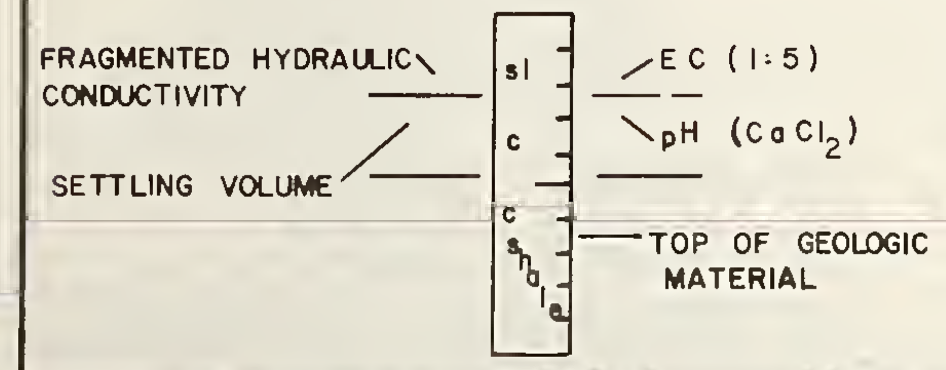


LAND SUITABILITY SYMBOLS



TWP. 19N SEC. 8 RANGE 90W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
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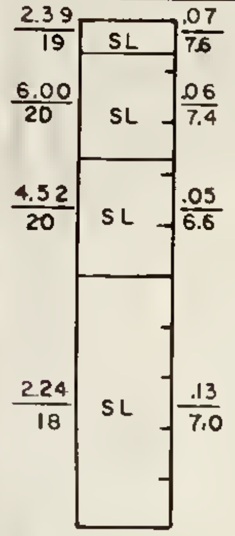
DESIGNED W.C. LAUBNER	SUBMITTED
DRAWN W.C. LAUBNER	RECOMMENDED
CHECKED T. CAPPELLUCCI	APPROVED
LM REGION, DEN., COLO.	FIGURE C2

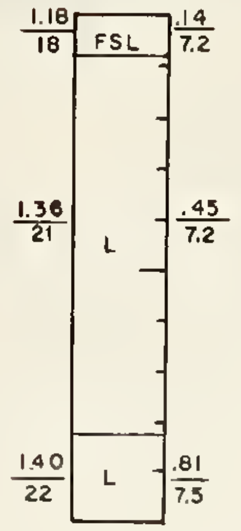
NO. 4-1



LOCATION: 150' NORTH 550' WEST OF SE CORNER OF NE $\frac{1}{4}$ SE $\frac{1}{4}$

PM: VALLEY FILL (ALLUVIUM)

NO. DH-6



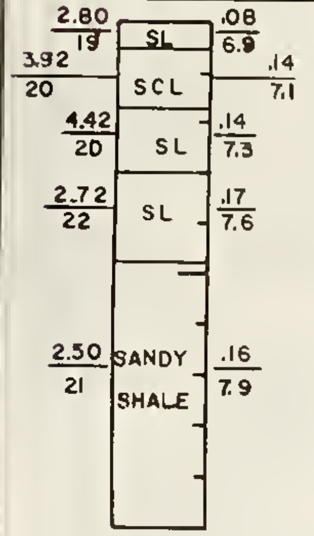
LOCATION: 400' SOUTH 300' EAST OF NW CORNER OF SW $\frac{1}{4}$ SW $\frac{1}{4}$

PM: ALLUVIUM

NO.

NO.

NO. 4-2



LOCATION: 350' SOUTH 150' EAST OF NW CORNER OF NE $\frac{1}{4}$ NE $\frac{1}{4}$

PM: SANDY SHALE

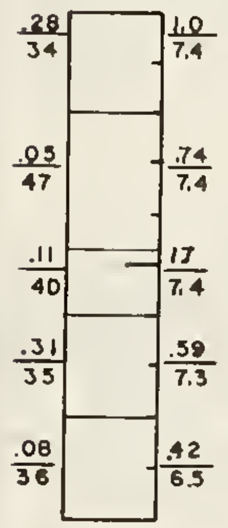
REMARKS: BIRDS FOOT SAGE, STRONG MEDIUM COLUMNAR STRUCTURE

NO.

NO.

NO.

NO. DH-5



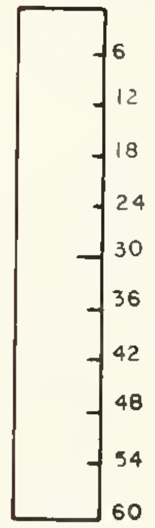
LOCATION: 150' SOUTH 150' WEST OF NE CORNER OF SE $\frac{1}{4}$ NW $\frac{1}{4}$

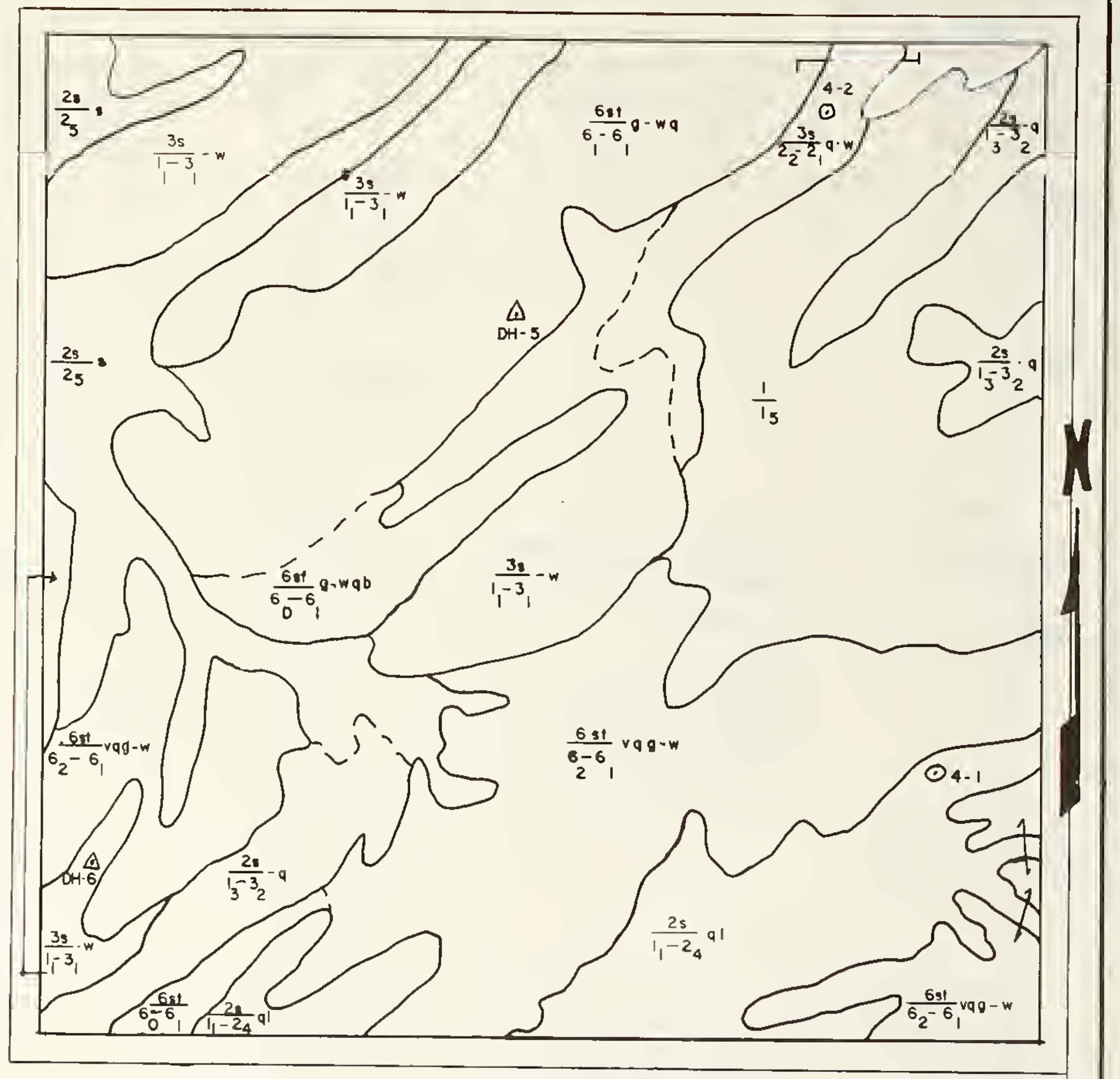
PM: SANDSTONE

NO.

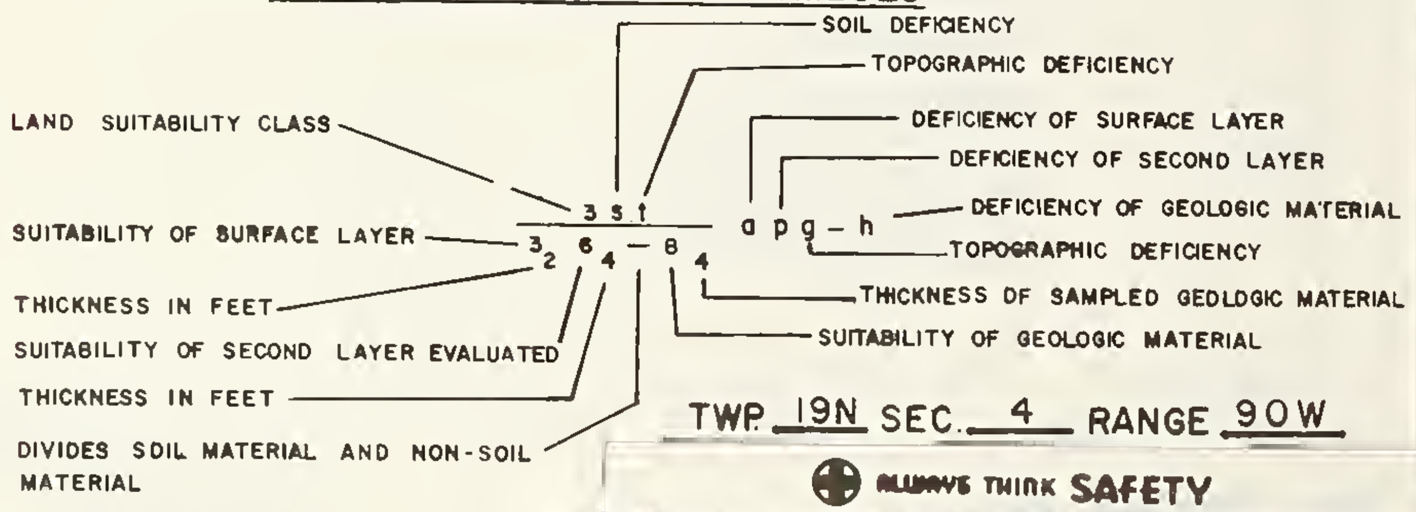
NO.

NO. DEPTH IN INCHES

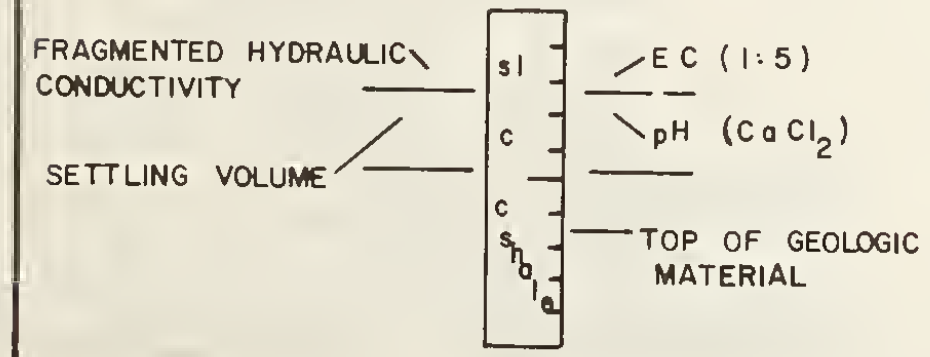




LAND SUITABILITY SYMBOLS



SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
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SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
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- w WEATHERABILITY
- k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
- b SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
- v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

SCALE: 1" = 1000'

RED RIM STUDY AREA — WYOMING

TWP. 19N SEC. 4 RANGE 90W

ALWAYS THINK SAFETY

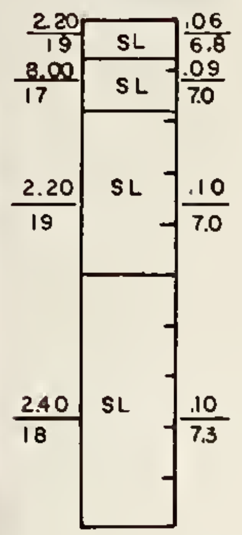
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

LAND SUITABILITY

LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED W.C. LAUBNER	SUBMITTED
DRAWN W.C. LAUBNER	RECOMMENDED
CHECKED T. CAPPELLUCCI	APPROVED
LM REGION, DEN., COLO.	FIGURE C3

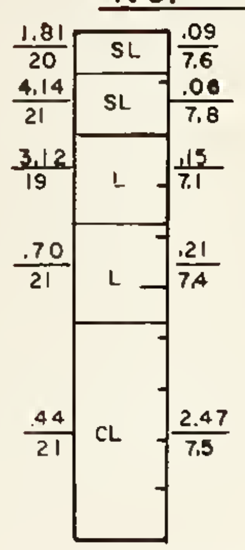
NO. 34-1



LOCATION: 500' NORTH 150' WEST OF SE CORNER OF NW $\frac{1}{4}$ SE $\frac{1}{4}$

PM: VALLEY FILL (ALLUVIUM)

NO. DH- 2



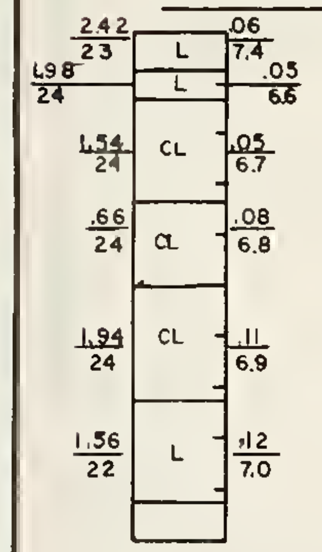
LOCATION: 250' SOUTH 500' EAST OF NW CORNER OF NW $\frac{1}{4}$ NW $\frac{1}{4}$

PM: HARD CALCAREOUS SAND

NO.

NO.

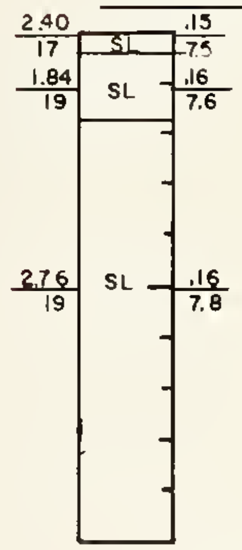
NO. 34-2



LOCATION: 200' NORTH 400' WEST OF SE CORNER OF NE $\frac{1}{4}$ SW $\frac{1}{4}$

PM: VALLEY FILL (ALLUVIUM)

NO. DH- 3



LOCATION: 150' SOUTH 200' WEST OF NE CORNER OF NE $\frac{1}{4}$ SW $\frac{1}{4}$

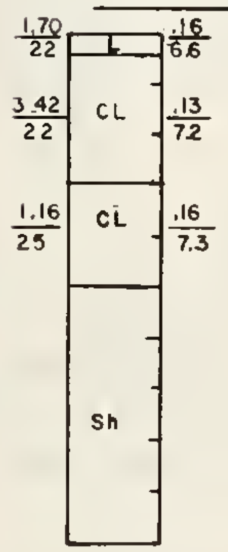
PM: VALLEY FILL (ALLUVIUM)

REMARKS: NEEDLELEAF SEDGE, NEEDLE AND THREAD, INDIAN RICEGRASS.

NO.

NO.

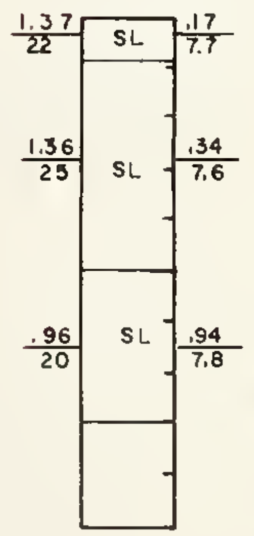
NO. 34-3



LOCATION: 600' SOUTH 450' EAST OF NW CORNER OF SW $\frac{1}{4}$ SW $\frac{1}{4}$

PM: SHALE

NO. DH- 4

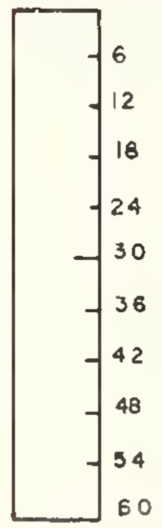


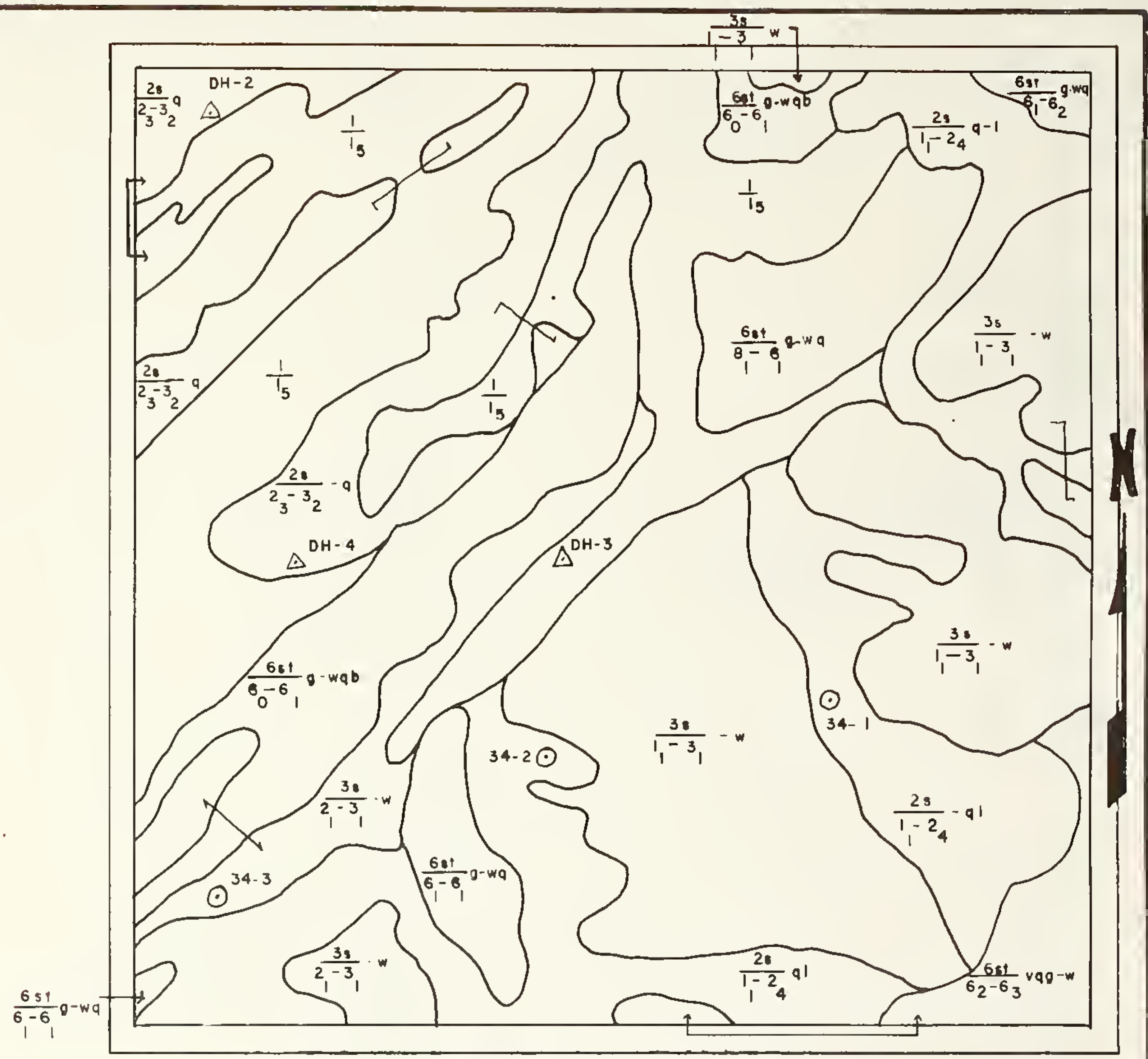
LOCATION: 100' SOUTH 500' EAST OF NE CORNER OF NW $\frac{1}{4}$ SW $\frac{1}{4}$

PM: SOFT CALCAREOUS SANDSTONE

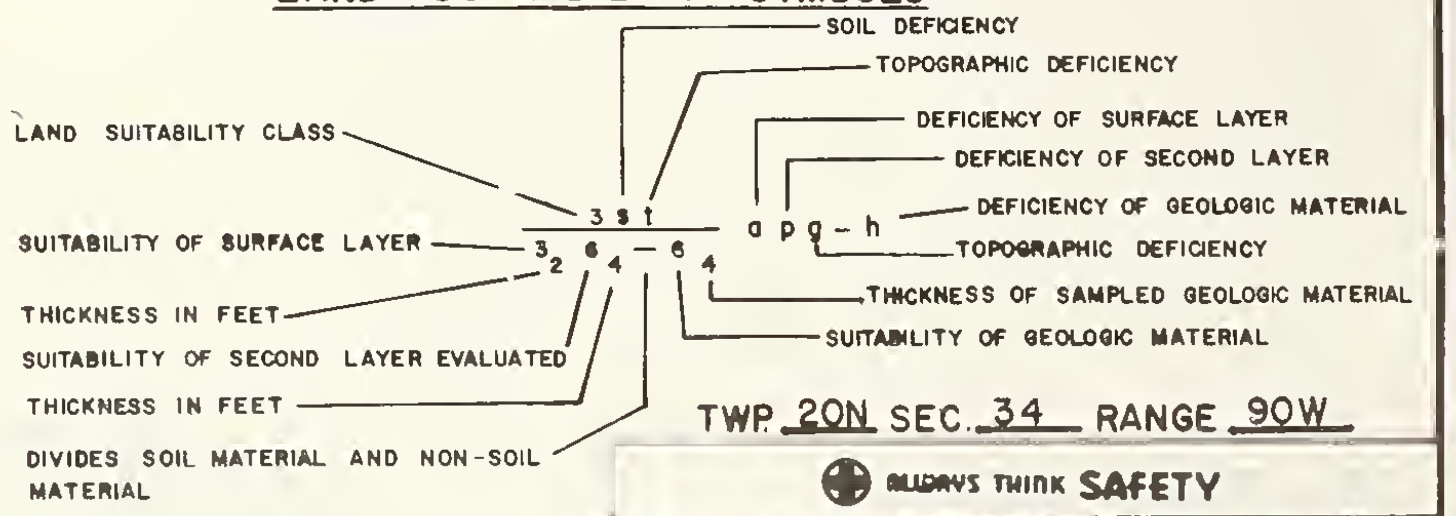
NO.

NO. DEPTH IN INCHES



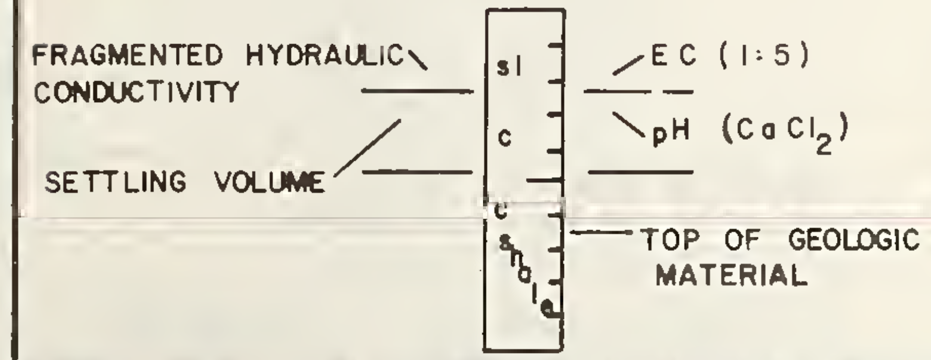


LAND SUITABILITY SYMBOLS



TWP. 20N SEC. 34 RANGE 90W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

- s SALINITY
- a SODICITY
- w WEATHERABILITY
- k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
- b SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
- v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

SCALE: 1" = 1000'

RED RIM STUDY AREA — WYOMING

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAND SUITABILITY

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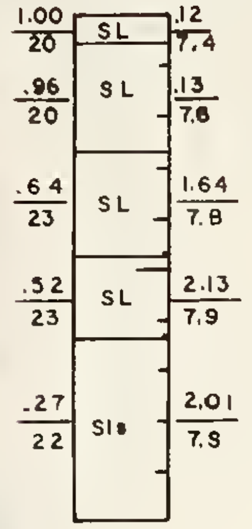
DESIGNED W.C. LAUBNER	SUBMITTED
DRAWN W.C. LAUBNER	RECOMMENDED
CHECKED T. CAPPELLUCCI	APPROVED
LM REGION, DEN., COLO.	FIGURE C4

NO. 28-3

LOCATION: SE $\frac{1}{4}$ SE $\frac{1}{4}$

PM: SOFT GRAYISH SILTSTONE



NO.

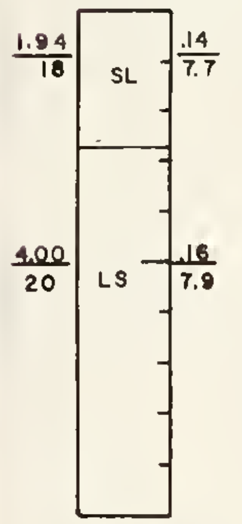
NO.

NO.

NO. DH-1

LOCATION: SE $\frac{1}{4}$ SE $\frac{1}{4}$

PM: ALLUVIUM



NO.

NO.

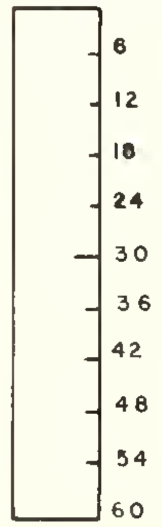
NO.

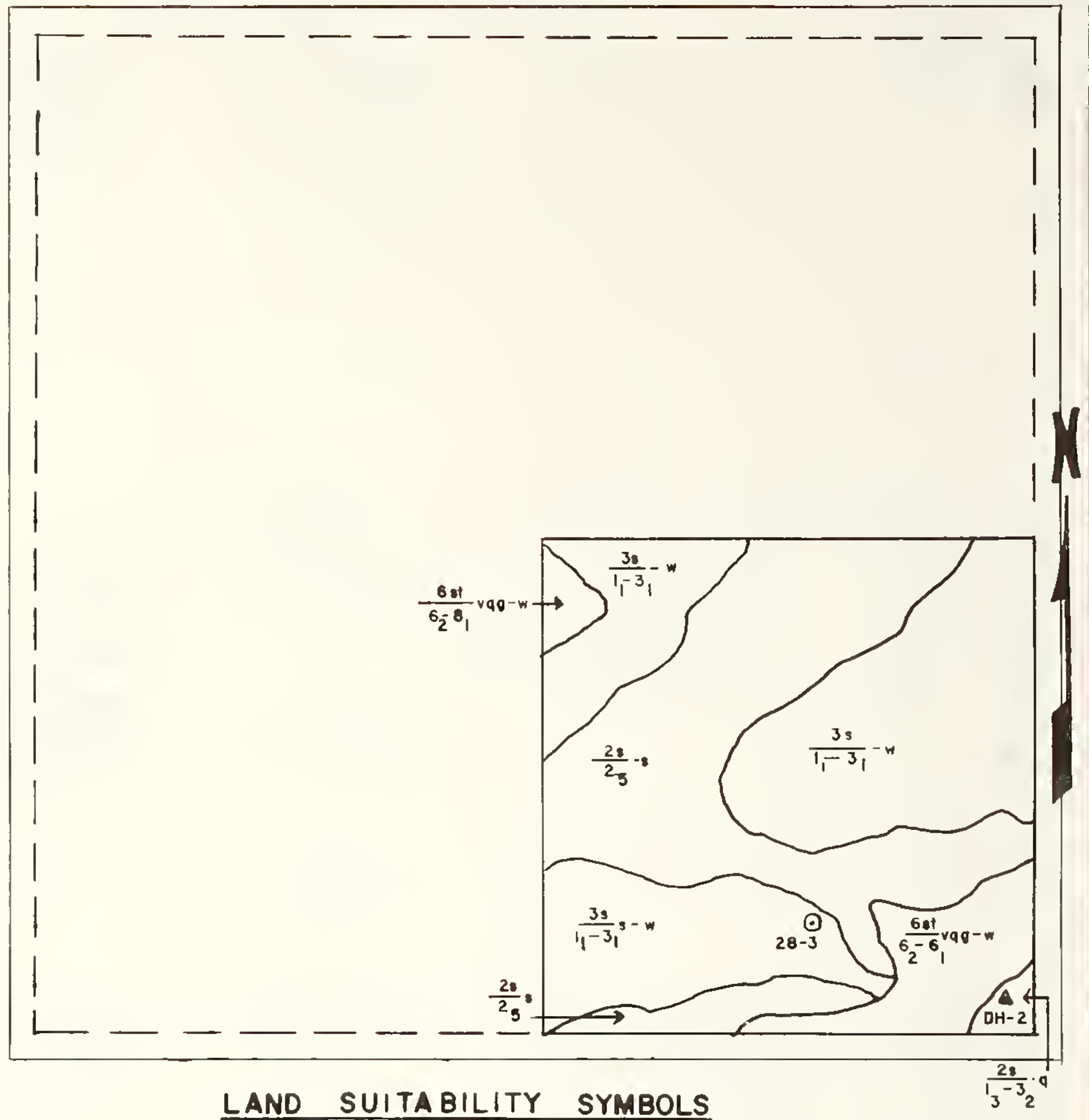
NO.

NO.

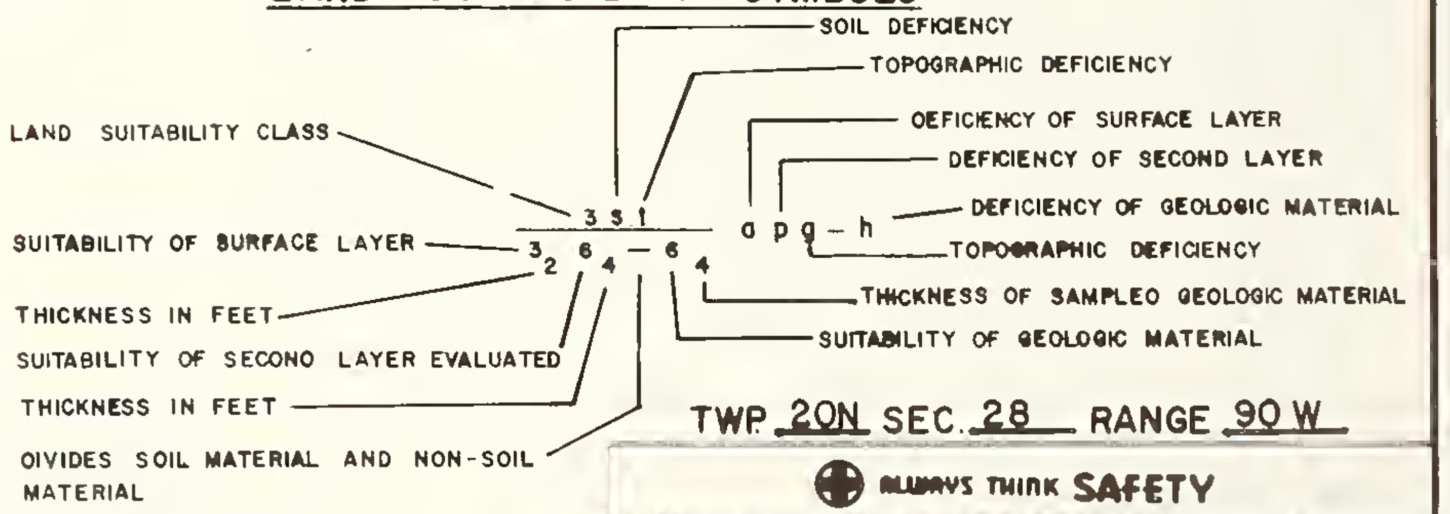
NO.

NO. DEPTH IN INCHES

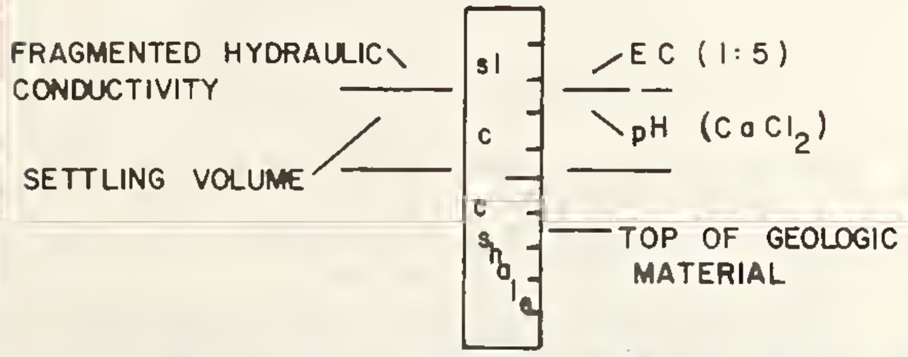




LAND SUITABILITY SYMBOLS



SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

- s SALINITY
- a SODICITY
- w WEATHERABILITY
- k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
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- v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
- h VERY FINE TEXTURE (CLAYS)
- q AVAILABLE MOISTURE CAPACITY
- i INFILTRATION
- p PERMEABILITY
- x STONINESS

TOPOGRAPHY DEFICIENCIES

- g SLOPE
- c SURFACE ROCKS
- r BEDROCK OUTCROPS

SCALE: 1" = 1000'

RED RIM STUDY AREA — WYOMING

TWP. 20N SEC. 28 RANGE 90 W

ALWAYS THINK SAFETY

UNITED STATES
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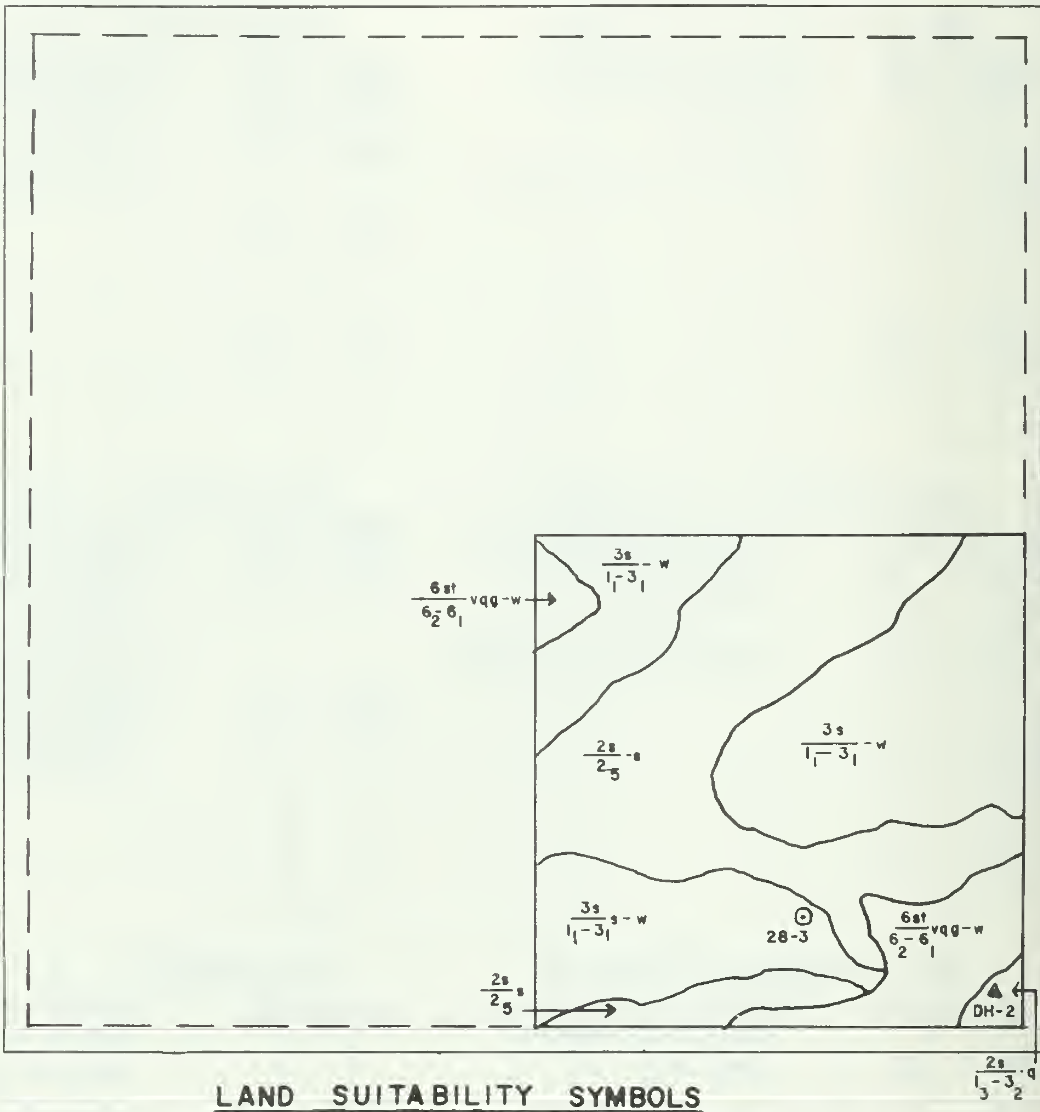
DRAWN W.C. LAUBNER RECOMMENDED
CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO. | FIGURE C5



LAND SUITABILITY SYMBOLS

3 s t / 3 2 6 4 — 6 4 a p g – h

- SOIL DEFICIENCY
- TOPOGRAPHIC DEFICIENCY
- LAND SUITABILITY CLASS
- DEFICIENCY OF SURFACE LAYER
- DEFICIENCY OF SECOND LAYER
- DEFICIENCY OF GEOLOGIC MATERIAL
- SUITABILITY OF SURFACE LAYER
- TOPOGRAPHIC DEFICIENCY
- THICKNESS IN FEET
- THICKNESS OF SAMPLED GEOLOGIC MATERIAL
- SUITABILITY OF SECOND LAYER EVALUATED
- SUITABILITY OF GEOLOGIC MATERIAL
- THICKNESS IN FEET
- DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL

CIES

S

SCALE: 1" = 1000'

RED RIM STUDY AREA — WYOMING

TWP. 20N SEC. 28 RANGE 90 W

ALWAYS THINK SAFETY

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DRAWN W.C. LAUBNER	RECOMMENDED
CHECKED T. CAPPELLUCCI	APPROVED
LM REGION, DEN., COLO.	FIGURE C5

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

TABLE C I

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ecx10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract $ecx10^3$ @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
1	RR-8-1	0.0-2.0	.20	.23	7.0	6.9	21			.23	1.6	.8	0.8										23.0			9.6
2	2	2.0-4.0	.16	.15		7.2	22			.32	2.8	.3	1.4								.18		23.0			9.2
3	3	4.0-6.0	.11	.09	7.7	6.9	24			.25	2.4	.1	1.2								.22		24.0			10.3
4	4	6.0-8.0	.10	.07	8.0	7.3	25			.30	2.5	.4	1.2								.20		29.0			8.2
5	5	8.0-13.0	.05	.03	7.9	7.4	23			.31	2.7	.3	1.4								.21		28.0			11.3
6	6	13.0-18.0	.01	.03	7.9	7.7	25			.64	6.2	.1	3.1	3.3	6.9	45.2	1.5	52.4	2.8		.42		31.0			12.7
7	7	18.0-21.0	.15	.14	8.1	6.7	24			.82	7.6	.4	3.8	4.2	9.2	76.4	1.5	48.8	3.7		.48	.03	30.0	0.1		11.1
8	8	21.0-29.0	.43	.62	8.7	7.3	18			.17	1.6	.1	0.8								.30		28.4			14.1
9	9	29.0-37.6	.35	.46	8.6	7.6	18			.26	2.0	.5	1.0								.10		14.0			7.2
10	10	37.6-48.0	11.52	4.34	8.5	6.4	23			.16	1.2	.5	0.6								.08		3.6			3.1
11	11	48.0-59.0	5.60	2.04	8.7	6.6	21			.18	1.2	.8	0.6								.16		8.4			3.2
12	12	59.0-69.0	5.86	.68	8.6	7.1	18			.21	2.0	.1	1.0								.10		13.0			8.9
13	13	69.0-79.4	5.38	1.28	8.5	7.4	26			.13	0.8	.8	0.4								.10		13.0			5.5
14	14	79.4-89.0	4.18	.94	8.5	7.6	21			.10	0.9	.2	0.4								.10		15.0			5.5
15	15	89.0-91.8	.11	.08	8.3	7.3	20			.18	1.3	.6	0.6								.24		47.0			16.3
16	16	91.8-95.0	.66	1.00	8.6	7.6	23			.14	1.0	.4	0.5								.36		33.0			12.0
17	17	95.0-100.0	3.26	2.82	8.8	7.8	22			.13	1.0	.4	0.5								.24		16.0			6.6
18	18	100.0-105.0	1.54	3.04	8.8	7.9	21			.15	1.2	.4	0.6								.34		20.0			8.7
19	19	105.0-110.0	1.58	2.54	9.0	6.7	26			.14	0.8	.9	0.4								.42		24.0			11.3
20	RR-8-20	110.0-114.6	1.66	1.78	9.1	7.1	26			.23	2.0	.3	1.0								.44		25.0			8.8
21	21	114.6-117.4	.04	.02	8.9	6.7	24			.21	0.7	2.4	0.4								.62		37.0			15.3
22	22	117.4-122.0	6.34	2.40	8.9	7.1	24			.14	0.8	.9	0.4								.32		16.0			6.4
23	23	122.0-132.0	3.44	2.40	9.0	7.5	21			.14	0.8	.9	0.4								.40		24.0			9.1
24	24	132.0-137.0	1.52	2.32	9.0	7.6	22			.14	0.6	1.5	0.3								.40		27.0			8.9
25	25	137.0-145.0	2.42	2.84	8.9	7.7	21			.15	1.0	.7	0.5								.38		20.0			8.5
26	26	160.7-170.7	.02	.04	8.5	7.8	27			.21	1.2	1.2	0.6								.70		52.0			17.7
27	27	170.7-190.0		.004	8.6	6.8	26			.45	4.0	.4	2.0	.73	3.3	5.4	0.4	55.4	0.30		.36	.18	36.0	0.5		14.8
28	28	190.0-190.5		.002	8.8	7.2	30			.49	4.4	.3	2.2	.52	2.5	4.2	0.3	49.5	0.21		.34	.22	32.0	0.7		13.1
29	RR-9- 1	0.0-2.5	5.00	4.60		7.5	18			.20											.30		10.0			4.2
30	2	2.5-4.5	2.48	1.32	7.6	7.6	19			.16											.18		9.00			4.0
31	3	4.5-9.0	1.04	.94	7.6	7.6	21			.30											.20		10.0			4.8
32	4	9.0	3.40	2.56	7.5	7.5	22			.23											.21		8.4			4.2
33	5	15.0-28.0	1.34	.98	7.7	7.5	23			.20											.22		6.8			3.0
34	6	28.0-31.5	.13	.10	7.7	7.6	30			.19											.22		22.0			11.4
35	7	31.5-35.0	15.00	5.81	7.8	7.7	17			.12											.16		4.6			2.3
36	8	35.0-35.5	.22	.54	7.7	7.0	18			.22											.40		7.0			3.1
37	9	35.5-37.5	.08	.15	7.3	6.7	27			.95				3.4	3.4	51.6	0.7	46.5	2.4		.36	.20	36.4	.55		12.7
38	10	37.5-41.3	.80	.84	7.6	6.9	21			.33											.30		7.6			5.2
39	RR-9-11	41.3-46.0	.15	.14	7.6	7.2	29			.38				2.2	2.5	27.2	0.7	49.4	1.3		.36	.24	21.0	1.1		9.9
40	12	46.0-53.7	.11	.11	7.6	7.2	30			.36				1.8	1.8	21.2	0.6	49.5	1.0		.34	.25	28.0	.89		11.2
41	13	57.[illegible]-65.8	.12	.16	7.6	6.6	31			.22											.32		9.6			6.4
42	14	65.8-67.3	2.08	1.20	7.6	6.7				.23											.30		2.8			2.6
43	15	67.3-72.7	.20	.21	7.7	7.2	25			.29											.38		9.0			5.8
44	16	72.7-82.2	.42	.50	7.6	7.1	47			.48				2.1	1.6	25.6	0.4	53.1	1.4		.38	.30	23.0	1.3		13.0
45	17	85.7-94.0	.12	.10	7.7	7.3	31			.25											.36		16.0			7.3
46	18	94.0-100.2	.15	.19	7.6	7.4	40			.41				1.2	1.1	12.8	0.4	54.0	0.7		.40	.34	30.0	1.1		11.5
47	19	100.2-105.0	.05	.07	7.4	7.0	38			.72				3.0	1.8	42.0	0.4	54.7	2.3		.34	.24	35.0	.69		14.6
48	20	105.0-109.5	1.52	1.04	7.6	7.3	20			.28											.36		3.6			3.4
49	21	109.5-118.7	.30	.33	7.4	6.6	21			.41				2.1	1.2	27.6	0.3	36.6	1.0		.36	.32	6.4			4.8
50	22	120.9-127.6	.18	.22	7.3	6.6	42			.40				2.3	1.5	29.2	0.4	51.3	1.5		.34	.26	38.0	.68		13.5
51	23	128.1-130.0	.19	.20	7.2	6.7	32			.36											.24		6.8			5.8
52	24	130.0-140.0	.13	.13	7.5	7.1	29			.19											.26		4.8			2.1
53	25	140.0-150.2	.62	.68	7.3	7.3	30			.28											.32		7.0			3.9
54	26	150.2-160.2	4.18	2.14	7.5	7.5	19			.16											.30		5.0			2.8
55	27	160.2-168.7	17.20	6.04	7.6	7.5	20			.17											.04		4.0			2.6
56	28	168.7-180.2	5.00	1.88	7.6	7.4	21			.17											.28		5.2			3.9
57	RR-10-1	0.0-1.0	2.74	3.06	7.7	7.5	22			.15											.18		17.0			6.5
58	2	1.0-2.5	3.68	2.52	7.8	7.6	23			.18											.34		16.0			6.3
59	3	2.5-3.5	5.72	1.80	7.9	7.5	20			.15											.36		13.2			5.7
60	4	18.3-22.3	18.34	6.00	7.9	7.4	22			.10											.27		20.0			7.1
61	5	22.3-28.3	3.72	11.64	7.8	6.2	23			.07											.30		18.0			8.7
62	6	28.3-33.5	15.60	9.74	7.8	6.4	23			.09											.31		15.0			7.2
63	7	33.5-37.5	5.13	4.74	7.6	6.5	23			.07											.30		24.0			7.1
64	8	37.5-39.0	.15	.32	7.6	6.9	43			.28											.36		38.0			3.7
65	9	39.[illegible]-44.0	4.20	5.46	7.7	7.1	23			.70				2.8	1.6	41.6	0.4	40.3	1.?		.30	.24	16.0	1.5		7.3

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

TABLE C1 continued

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity In./hr. 6th Hr.	Hydraulic Conductivity In./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR	Saturation Extract Sat %	Saturation Extract Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	% of Moisture 15 Bars
66	RR-10-10	44.0-48.3	9.16	6.98	7.7	6.4	22			.49				2.2	1.3	28.8	0.3	41.0	1.2		.36	.31	15.2	2.0		7.5
67	11	48.3-53.0	6.52	7.04	7.7	6.6	20			.46											.30		15.2			7.2
68	12	53.0-58.3	5.38	9.56	7.7	6.8	21			1.07				3.0	2.2	44.8	0.5	42.9	1.9		.36	.27	18.0	1.5		9.2
69	13	58.3-60.0	5.70	8.04	7.9	7.4	25			.27											.32		15.0			7.7
70	14	60.0-63.0	.25	.25	7.7	7.6	30			.40				1.5	2.2	16.0	0.8	49.5	0.8		.42	.32	20.0	1.6		9.6
71	15	63.0-68.3	.94	.98	7.7	6.7	25			.35				1.5	2.2	16.4	0.8	46.3	0.8		.44	.34	12.4	2.7		7.2
72	16	68.3-73.3	.42	.46	7.7	7.1	28			.36											.44		17.0			8.6
73	17	73.3-78.3	.15	.16	7.7	7.4	24			.35											.46		23.0			10.3
74	18	78.3-83.3	2.00	2.24	7.8	7.8	24			.32											.40		22.0			11.0
75	19	83.3-88.3	.39	.40	7.8	7.7	30			.32											.46		26.0			9.8
76	20	88.3-93.3	.66	.70	7.8	7.7	28			.34				1.4	2.1	15.2	0.8	43.7	0.7		.40	.31	15.2	2.0		8.0
77	21	93.3-98.3	.004	.04	7.7	7.6	65			.42				1.5	1.8	16.0	0.6	58.1	.93		.46	.36	50.0	.72		18.6
78	22	98.3-103.0	.002	.05	7.7	7.6	57			.42											.50		54.0			24.1
79	23	103.0-110.0	.001	.04	7.5	7.3	57			.67				2.9	2.4	39.2	0.5	65.0	2.5		.56	.40	60.0	.67		20.7
80	24	110.0-117.8	.27	.18	7.7	7.6	34			.23											.36		21.0			10.0
81	25	117.8-123.0	.35	.46	7.7	6.5	25			.29											.36		11.0			7.6
82	26	123.0-128.3	2.20	.86	7.7	6.9	21			.21											.30					4.1
83	27	128.3-133.9	3.88	1.14	7.8	6.8	21			.17											.32					3.8
84	28	134.5-140.0	.08	.08	7.8	7.2	34			.33				1.5	0.8	19.2	0.3	50.0	.96		.36	.32	52.0	.62		16.3
85	29	140.0-143.5	.05	.05	8.0	7.4	31			.26											.36		24.0			12.1
86	30	143.5-148.5	1.10	.57	7.5	6.2	23			.90				2.9	1.0	42.4	0.2	42.4	1.8		.30	.26	14.0	1.9		7.7
87	31	148.5-155.5	10.62	10.00	7.7	6.4	18			.50				2.1	0.7	28.4	0.2	39.2	1.1		.30	.27	6.6	4.1		3.7
88	32	155.5-158.3	16.26	10.00	7.8	6.6	19			.20											.31		7.0			4.1
89	33	158.3-163.3	21.56	10.00	7.7	6.8	19			.17											.30		6.8			3.8
90	34	163.3-168.3	25.94	10.00	7.6	6.9	19			.26											.30		6.2			3.6
91	35	168.3-175.0	23.22	10.00	7.7	6.8	18			.21											.32		7.6			3.4
92	36	175.0-181.0	26.00	10.00	7.8	7.0	18			.26											.30		10.0			3.2
93	37	181.0-188.3	62.80	10.00	7.6	7.2	18			.54				2.8	1.0	40.8	0.2	39.9	1.6		.36	.32	7.6	4.2		2.1
94	38	188.3-192.0	65.60	10.00	7.4	7.2	18			.90				2.6	0.75	38.0	0.2	39.9	1.5		.30	.27	6.4	4.2		1.7
95	39	192.0-198.3	47.70	10.00	7.6	7.2	18			.27											.30		8.0			2.6
96	RR-4-1	0.0-1.0	5.86	2.04	7.6	7.4	24			.26											.44		24.0			8.2
97	2	1.0-2.5	.35	.36	7.7	7.4	32			.32				1.5	6.5	11.6	2.7	46.7	.54		.56	.26	38.0	.68		10.5
98	3	2.5-6.5	3.54	.84	7.7	7.7	17			.43				4.5	19.0	31.2	4.8	26.5	.83		.58	.08	7.6	1.1		2.2
99	4	6.5-8.0	4.28	.88		7.8	19			1.08				3.6	12.0	39.6	2.7	28.6	1.1		.40	.06	6.0	1.0		1.6
100	5	8.0-9.3	5.38	.80	8.0	7.9	20			.25											.34		6.0			1.5
101	6	9.3-19.0	12.52	6.00	7.9	6.8	16			.25											.12		5.2			1.4
102	7	19.0-23.0	10.08	6.00	7.9	7.1	19			.23											.14		7.6			2.1
103	8	23.0-29.0	.70	.80	8.0	7.3	25			.16											.16		16.0			4.9
104	9	29.0-33.4	10.64	6.00	8.0	7.2	19			.16											.02		3.0			1.6
105	10	33.4-39.0	2.84	1.66	8.0	7.4	19			.20											.04		5.2			1.3
106	11	39.0-41.0	.42	.38	7.8	7.3	26			.19											.01		5.4			3.9
107	12	41.0-48.5	.05	.07	7.7	7.2	50			.21											.10		32.0			11.8
108	13	48.5-53.3	.16	.14	7.8	7.4	35			.14											.08		11.2			5.7
109	14	53.3-59.0	.14	.14	7.8	7.3	35			.16											.10		16.0			8.1
110	15	59.0-64.0	.02	.08	7.8	7.4	52			.21											.12		28.0			12.1
111	16	64.0-69.0		.03	7.8	6.7	65			.27											.11		26.0			14.2
112	17	69.0-74.0	.01	.07	7.8	6.9	54			.24											.11		25.0			13.3
113	18	74.0-76.0	1.12	2.16	6.7	5.9	39			.36				3.5	2.7	52.0	0.5	54.1	2.8		.32	.17	64.0	.27		17.5
114	19	77.0-78.5	.47	.76	6.9	6.2	50			.21											.28		40.0			16.1
115	20	78.5-82.0	.60	.76	6.9	6.4	52			.21											.20		28.0			11.9
116	21	82.0-87.7	.17	.28	7.1	6.5	49			.20											.24		30.0			14.4
117	22	87.7-94.0	.11	.11	7.3	7.0	48			.25											.44		35.0			16.0
118	23	94.0-100.7	.20	.21	7.6	7.3	45			.25											.40		40.0			14.7
119	24	100.7-103.7	.12	.15	7.7	7.3	40			.21											.32		36.0			11.8
120	25	103.7-110.7	.03	.06	7.8	7.2	45			.17											.50		47.0			16.1
121	26	110.7-115.0	.006	.03	7.9	6.8	42			.18											.40		36.0			14.3
122	27	115.0-120.7	.13	.14	7.8	7.0	39			.21											.34		38.0			11.0
123	28	120.7-125.8	.19	.16	7.0	6.7	38			.45				3.2	5.6	40.8	1.2	52.1	2.1		.50	.21	50.4	.42		15.8
124	29	126.8-129.5	.19	.27	7.2	6.6	39			.21											.34		42.0			13.6
125	30	141.0-142.0	.92	.50	6.6	5.7	38			.67				3.6	10.3	40.0	2.3	66.8			.42		50.0			18.1
126	31	142.4-148.0	.46	.62	7.2	6.8	50			.22											.36		74.0			15.1
127	32	148.3-153.0		.01	7.7	7.0	75			.20											.32		62.0			14.3
128	33	153.0-158.3	.35	.68		6.9	30			1.03				3.1	4.2	42.8	0.9	64.7			.18		28.0			14.8
129	RR-6- 1	0.0-1.0	2.66	3.56	7.8	7.0	28			.16											.40		28.4			11.9
130	2	1.0-2.5	.10	.13	7.4	7.1	36			1.36				2.2	3.1	26.0	0.9	55.8			1.40		52.0			15.4

TABLE CI continued

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
131	RR-6-3	2.5-5.0	.13	.13	7.3	7.0	37			1.08				4.0	14.0	45.6	2.9	46.4			.84		43.0			11.3
132	4	5.0-7.5	1.84	.86	4.7	4.4	25			.54				3.7	10.5	38.8	2.4	55.9			.54		48.0			18.8
133	5	12.5-17.0	4.22	2.24		3.8	30			.88				4.0	3.5	49.6	0.7	40.2			.32		28.4			9.7
134	6	17.0-21.5	1.62	1.94	3.8	3.7	33			.90				4.3	4.5	55.2	0.9	60.0	3.31		.34	.07	33.0	.21		20.3
135	7	21.5-24.5	2.80	1.88	4.0	3.9	29			.79				5.1	3.0	71.2	0.5	61.4	4.37		.36	.18	68.0	.26		21.0
136	8	25.0-28.4	.22	.27	3.3	3.3	24			2.09				5.0	2.5	68.4	0.4	72.7	4.97		.48	.30	68.0	.44		25.4
137	9	28.4-32.0		.04	5.4	5.1	65			.29											.16		36.0			13.4
138	10	36.0-40.0	.16	.18		6.3	49			.37				1.8	1.0	20.4	0.3	60.2	1.23		.18	.12	38.0	.32		15.0
139	11	40.0-42.0	.11	.15	6.6	6.6	42			.22											.14		28.4			11.7
140	12	44.1-48.1	.06	.05		6.8	43			.32											.20		50.0			18.2
141	13	48.1-50.0	.08	.07	6.6	6.4	36			.19											.14		43.0			13.1
142	14	50.0-55.2	1.56	1.10		6.3	21			1.36				2.7	1.5	39.2	0.3	33.3	1.31		.10	.05	10.0	.50		6.4
143	15	55.2-61.3	8.08	2.26	6.6	6.5	20			.14											.14		10.0			4.1
144	16	61.3-64.8	10.44	3.00	6.8	6.5	18			.14											.10		7.4			3.6
145	17	64.8-70.0	7.44	4.00	6.8	6.6	17			.20											.10		4.0			2.8
146	18	70.0-78.5	13.22	4.00	6.9	6.6	19			.14											.10		10.0			4.4
147	19	78.5-81.5	6.06	3.00	6.9	6.7	19			.24											.10		7.8			3.7
148	20	81.5-91.5	7.76	3.00	7.2	6.7	17			.18											.18		7.2			4.0
149	21	91.5-96.5	25.24	6.00	7.5	6.8	17			.10											.16		11.4			4.4
150	22	96.5-104.5	12.88	6.00	7.6	6.9	17			.12											.16		10.0			4.1
151	23	104.5-111.5	4.64	1.02	7.3	6.7	17			.15											.18		7.0			3.2
157	24	111.5-116.5	.19	.21	7.4	7.0	28			.24											.14		28.0			12.5
153	25	116.5-121.5	.11	.14	7.5	7.2	40			.26											.16		40.0			15.4
154	26	121.5-127.5	.19	.22	7.2	7.0	37			.40				2.8	2.3	38.0	0.5	58.3	2.22		.18	.05	70.0	.07		16.9
155	27	127.5-134.9	.04	.04	7.5	7.1	35			.23											.14		29.0			12.7
156	28	134.9-137.0	.22	.32	7.6	7.2	24			.16											.10		17.0			6.6
157	29	138.0-141.0	.14	.15	6.7	6.6	30			.31											.10		22.0			10.5
158	30	141.0-147.5	.22	.31	6.4	5.9	32			.22											.10		15.2			8.4
159	RR-7-1	0.0-0.9	1.28	1.42	7.4	6.3	20			.09											.10		12.0			6.2
160	2	0.9-2.3	.94	.92	7.9	6.7	22			.12											.24		12.0			7.7
161	3	2.3-3.1	.10	.08	9.0	7.4	25			.38				3.5	27.0	10.0	12.1	30.3	.30		1.3	.48	11.6	4.1		6.0
162	4	3.1-5.0	1.24	.72	8.5	7.7	19			.87				8.7	52.0	60.0	9.5	29.7	1.78		2.6	1.06	11.6	9.1		6.9
163	5	5.0-7.0	.72	.84	8.2	7.6	21			.22											.26		27.0			8.6
164	6	7.0-12.0	4.80	1.04	8.3	7.6	19			.10											.10		14.8			5.5
165	7	12.0-16.0	1.40	.86	8.3	7.6	22			.12											.12		14.4			3.5
166	8	16.0-19.5	3.06	.88	8.2	7.7	19			.12											.12		12.8			3.9
167	9	19.5-27.1	5.20	.76	8.2	7.7	19			.13											.10		13.0			7.5
168	10	27.1-30.0	.32	.29	7.8	7.5	31			.84				3.3	0.8$	48.4	0.2	53.6	2.59		.10	.05	58.0	.09		14.0
169	11	32.0-34.0	.28	.33	7.4	7.4	45			2.38				5.5	1.1	77.6	0.4	70.4	5.46		.20	.12	126.0	.10		
170	12	34.0-35.6	.19	.20	7.0	5.7	32			.28											.20		39.0			17.8
171	13	45.9-47.9	.15	.15		6.2	41			.53				2.3	3.0	27.6	0.8	42.6	1.18		.16	.03	20.0	.15		8.0
172	14	47.9-54.0	.22	.23	6.7	6.6	50			.13											.12		12.6			5.0
173	15	54.0-61.0	.34	.35	6.9	6.8	53			.09											.12		4.0			3.1
174	16	61.0-68.0	3.40	.98	8.0	6.8	22			.09											.16		6.6			2.6
175	17	68.0-73.0	4.08	.92	8.1	6.9	23			.11											.14		5.6			2.4
176	18	73.0-76.0	2.48	.92	8.1	7.1	17			.12											.22		8.4			3.9
177	19	76.0-80.0	4.48	1.08	8.3	7.4	24			.14											.22		12.2			4.2
178	RR-1-1	0.0-1.0	3.16	1.08	8.2	7.5	19			.10											.10		10.0			4.0
179	2	1.0-7.7	4.88	1.00	8.2	7.6	16			.28											.70		6.4			2.2
180	3	10.5-16.0	10.00	3.00	8.3	7.6	20			.13											.12		3.6			2.0
181	4	16.0-21.4	7.20	3.00	8.1	6.7	20			.20											.16		5.6			2.3
182	5	21.4-24.0	5.24	.84	8.5	7.0	17			.10											.10		7.6			3.0
183	6	24.0-31.4	8.24	3.00	8.4	7.2	21			.12											.10		5.0			2.0
184	7	31.4-36 0	6.06	.68	8.4	7.3	22			.10											.10		4.2			1.9
185	8	36.0-41.4	1.36	1.18	8.4	7.3	20			.11											.06		6.4			2.1
186	9	41.4-47.0	9.04	2.08	8.4	7.4	17			.08											.10		3.8			2.9
187	10	47.0-55.5	4.08	1.16	8.3	7.5	20			.09											.10		6.8			4.0
188	11	55.5-57.0	.09	.12	8.1	7.4	27			.15											.18		30.0			14.4
189	12	57.0-65.0	3.86	1.40	8.0	7.4	22			.08											.04		6.8			3.5
190	13	65.0-73.0	3.64	1.12	8.0	7.5	51			.33											.22		22.4			13.1
191	14	73.0-81.0	2.58	.96	8.4	6.7	19			.07											.10		6.4			7.8
192	15	87.8-90.	15.35	3.00	8.1	7.1	20			.08											.10		6.4			4.1
193	RR-2-1	0.0-1.0	10.28	3.00	8.4	7.2	20			.18											.24		24.0			8.2
194	2	1.0-2.7	.23	.28	9.2	7.6	24			.18											.14		20.0			7.3
195	3	18.9-22.0	13.60	3.00	8.2	7.7	33			.54				4.4	6.0	55.6	1.1	50.8	2.82		.84	.54	34.0	1.59		
196	4	22.0-24.0	.03	.04	8.7	7.7	19			.15											.60		3.0			13.0
																										3-1

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

TABLE CI continued

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
197	5	24.0-30.0	.42	.47	7.5	7.5	36			.41				2.9	3.1	35.2	0.7	54.2	1.91		.12		38.0			12.9
198	6	30.0-37.0		.008	6.1	5.7	24			.82				4.5	3.2	63.6	0.6	48.4	3.08		.38	.23	44.0	.52		12.3
199	7	44.0-48.0	3.24	.96	8.1	6.2	25			.08											.36		4.8			2.7
200	8	48.0-53.5	.35	.88	7.5	6.4	37			.37											.08		46.0			16.9
201	9	53.5-57.0	.15	.20	8.1	7.1	27			.34											.34		22.0			9.1
202	10	57.0-62.5	.88	.80	8.3	7.3	20			.27											.22		6.8			4.1
203	11	62.5-66.0	.17	.20	8.4	7.5	30			.26											.20		13.0			6.0
204	12	67.0-72.0	.20	.29	7.5	7.3	25			.52				3.4	3.3	46.0	0.7	39.6	1.82		.20	.07	20.0	.35		8.1
205	13	72.0-78.4	.90	.86	7.4	7.2	20			.76				3.9	3.3	58.0	0.6	37.8	2.19		.32	.20	11.0	1.8		4.7
206	14	78.4-86.0	7.26	1.60	7.5	6.7	19			.51				3.4	2.7	50.4	0.5	45.5	2.29		.26	.14	11.6	1.2		4.6
207	15	86.0-92.0	15.26	5.00	8.3	6.9	19			.26											.22		3.2			1.7
208	16	92.0-100.0	4.96	1.12	8.4	7.0	19			.46				3.2	3.0	46.0	0.6	29.7	1.37		.20	.11	3.8	2.9		3.1
209	17	100.0-108.9	5.40	.88	7.7	7.1	19			.93				4.6	3.4	52.0	0.7	34.4	1.79					5.8		3.5
210	18	108.9-118.9	8.30	4.00	8.0	7.2	19			.88				5.8	5.0	57.6	0.9	35.9			.14		4.8			2.4
211	19	118.9-125.0	18.20	5.00	7.8	6.3	19			.74				5.0	3.5	81.0	0.6	36.2			.14	.01	3.8	.26		2.0
212	20	125.0-128.9	6.74	2.04		6.6	18			1.36				6.2	3.6	112.8	0.5	33.6			.12		6.2			3.0
213	21	128.9-138.9	13.28	3.00	7.0	6.5	20			.62				4.0	3.6	63.2	0.6	35.4			.14	.01	3.2	.31		1.3
214	22	138.9-147.9	10.22	3.00		7.3	21			.58				4.0	2.5	65.2	0.4	32.5			.12	.04	3.0	1.3		1.3
215	23	147.9-154.5	.88	1.04	8.0	7.4	18			.56				4.0	2.4	60.0	0.4	25.6			.12	.06	6.4	.94		2.8
216	24	168.0-168.9	.13	.18	8.1	7.5	33			.27											.18		32.0			11.1
217	RR-5-1	0.0-1.0	.29	.28	7.8	7.4	34			1.00				3.3	13.0	36.0	3.1	58.4			.22		50.0			14.7
218	2	1.0-2.3	.002	.05	7.6	7.4	47			.74				3.4	5.7	43.2	1.2	65.9			1.54	1.16	42.0	2.8		17.2
219	3	2.3-3.0	.06	.11	7.6	7.4	40			1.77				3.4	6.7	43.2	1.4	60.7			.88	.47	47.0	1.0		16.4
220	4	3.0-4.0	.22	.31	7.4	7.3	35			.59				3.5	5.2	46.0	1.1	57.3			1.10	.80	50.0	1.6		13.3
221	5	4.0-5.0	.10	.08	7.6	6.5	36			.42				2.8	3.6	36.8	0.8	51.3			.64	.46	41.0	1.1		12.8
222	6	5.0-8.0	2.05	1.16	7.9	6.9	21			.52				3.6	3.7	51.7	0.7	41.8			.46	.31	16.0	1.9		5.6
223	7	8.0-16.0	1.20	.88	8.3	7.1	22			.29											.36		25.0			11.8
224	8	16.0-22.0	1.50	.96	8.4	7.2	21			.25											.44		24.0			11.2
225	9	22.0-28.0	1.45	1.24	8.4	7.3	20			.29											.46		23.0			11.6
226	10	28.0-34.0	3.14	1.72	8.8	7.4	20			.18											.44		21.0			8.4
227	11	34.0-40.0	3.60	1.68	8.6	7.4	22			.20											.44		24.0			10.4
228	12	40.0-46.0	4.96	1.44	8.0	7.5	24			.17											.28		22.0			9.8
229	13	46.0-52.0	5.50	3.00	7.7	7.4	24			.16											.26		25.0			10.6
230	14	52.0-60.0	4.90	3.00	7.8	7.4	23			.20											.34		20.0			9.4
231	15	60.0-68.0	5.13	3.00	7.6	6.7	23			.13											.34		23.0			9.2
232	16	68.0-77.7	4.64	3.00	8.1	6.8	21			.14											.38		18.4			7.1
233	17	90.7-97.4	-	.004	8.0	7.2	78			.17											.32		28.0			17.3
234	18	97.4-98.1	-	.02	8.1	7.3	70			.22											.36		34.0			22.2

TABLE C I continued

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity In./hr. 6th Hr.	Hydraulic Conductivity In./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR	Saturation Extract Sat %	Saturation Extract Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	% of Moisture 15 Bars
235	RRS-18-1-1	0-4	1.26	1.92	8.2	7.8	17			.09											.38		21.0			7.0
236	2	4-14	2.36	1.32	8.3	7.7	21			.10											.12		22.0			
237	3	14-32	3.70	3.26	8.6	7.8	20			.31											.12		22.0			8.3
238	4	32-60	1.10	1.00	8.3	8.1	19			1.44											.46		15.0			6.2
239	RRS-18-5-1	0-3	2.70	2.40	8.0	7.8	18			.07											2.04		14.0			3.6
240	2	3-6	5.04	4.62	7.7	7.6	20			.05											.08		18.0			
241	3	6-12	7.38	6.60	7.6	6.7	19			.11											.06		16.0			4.1
242	4	12-18	7.26	3.30	7.5	6.9	18			.40											.08		16.0			5.8
243	5	18-26	7.18	1.68	8.2	7.0	18			.08											.10		14.0			4.7
244	RRS8-1- 1	0-3	5.16	3.88	7.6	7.0	16			.04											.10		12.4			4.0
245	2	3-11	4.02	2.94	8.1	6.9	18			.08											.14		20.0			7.7
246	3	11-30	2.46	2.60	8.4	7.1	19			.10											.20		19.0			5.3
247	4	30-60	2.72	3.42	8.9	7.4	18			.17											.90		14.0			6.8
248	RRS8-2- 1	0-4	5.66	2.50	8.2	7.5	16			.06											.12		7.2			2.2
249	2	4-36	3.24	2.98	8.3	7.4	19			.08											.14		9.4			3.4
250	3	36-6	1.58	1.14	8.6	7.5	20			.09											.20		12.0			1.9
251	RRS34-1- 1	0-4	4.80	2.20	7.7	6.8	19			.06											.14		16.0			3.2
252	2	4-10	16.18	8.00	8.2	7.0	17			.09											.14		20.0			5.2
253	3	10-30	5.92	2.20	8.3	7.0	19			.10											.20		22.0			17.5
254	4	30-60	3.00	2.40	8.5	7.3	18			.10											.10		16.0			4.4
255	RRS28-3- 1	0-3	1.20	1.00	8.5	7.4	20			.12											.26		20.0			6.8
256	2	3-16	1.18	.96	8.7	7.6	20			.13											.26		17.2			1.9
257	3	16-28	.70	.64	8.2	7.8	23			1.64				5.56	20.0	73.0	3.31	45.2	3.3		1.2	.30	16.0	1.9		9.0
258	4	28-38	.48	.52	8.3	7.9	23			2.13				9.44	41.6	114.0	5.51	52.1	5.9		3.0	.83	22.0	3.8		10.0
259	5	38-60	.23	.27	8.1	7.9	22			2.01				8.87	36.4	116.0	4.78	49.0	5.7		2.2	.42	25.0	1.7		10.0
260	RRS34-2- 1	0-4	1.68	2.42	7.7	7.4	23			.06											.08		24.0			6.8
261	2	4-7	1.52	1.98	7.4	6.6	24			.05											.08		31.0			6.9
262	3	7-20	1.90	1.54	7.5	6.7	24			.05											.08		32.0			8.9
263	4	20-30	.60	.66	7.8	6.8	24			.08											.10		35.0			10.2
264	5	30-44	2.18	1.94	8.2	6.9	24			.11											.16		33.0			10.2
265	6	44-56	.90	1.56	8.1	7.0	22			.12											.20		30.0			9.4
266	RRS18-3- 1	0-3	1.24	1.84	7.9	7.0	21			.10											.16		26.0			10.4
267	2	3-6	2.56	4.00	7.6	7.1	22			.06											.10		26.0			7.7
268	3	6-9	1.52	2.38	7.5	7.0	22			.06											.14		29.0			5.1
269	4	9-18	3.28	4.30	8.0	7.1	23			.13											.16		33.0			7.2
270	5	18-30	.60	.63	8.0	7.4	23			.15											.20		20.0			11.0
271	RRS34-3- 1	0-2	1.72	1.70	8.1	6.9	22			.16											.22		42.0			11.4
272	2	2-18	3.82	3.42	8.1	7.2	22			.13											.20		41.0			9.3
273	3	18-30	1.02	1.16	8.1	7.3	25			.16											.12		39.0			14.0
274	RRS18-4- 1	0-2	1.00	1.50	7.9	7.3	20			.14											.08		27.6			8.1
275	2	2-20	1.16	1.40	8.0	7.4	18			.14											.10		18.0			3.2
276	3	20-60	.33	.36	8.1	7.5	23			.18											.22		31.0			14.0
277	RRS18-2- 1	0-8	9.64	4.94	8.0	7.5	19			.13											.12		18.0			5.[illegible]
278	RRS8-3- 1	0-8			9.2	8.0	105			1.05				8.04	56.4	7.8	28.6	47.9	.37		12.0	9.3	36.0	25.8		15.8
279	RRS4-1- 1	0-4	5.00	2.39	7.6	7.6	19			.07											.08		14.0			7.3
280	2	4-16	10.24	6.00	7.5	7.4	20			.06											.06		14.0			5.0
281	3	16-30	8.52	4.52	7.3	6.6	20			.05											.04		25.0			5.0
282	4	30-60	3.96	2.24	7.8	7.0	18			.13											.10		18.0			7.8
283	RRS4-2- 1	0-3	3.08	2.80	7.6	6.9	19			.08											.06		25.0			8.3
284	2	3-10	2.62	3.92	8.0	7.1	20			.14											.10		33.0			10.7
285	3	10-18	8.56	4.42	8.1	7.3	20			.14											.18		38.0			9.4
286	4	18-28	4.16	2.72	8.7	7.6	22			.17											.80		28.0			18.8
287	5	28+	8.48	2.50	9.0	7.9	21			.16											1.5		31.0			8.6
288	RRS-1- 1	0-16	4.14	1.94	8.2	7.7	18			.14											.04		12.4			5 [illegible]
289	2	16-60	5.90	4.00	8.6	7.9	20			.16											.32		5.8			1.[illegible]
290	RRS-2- 1	0-4	1.72	1.81	7.7	7.6	20			.09											.10		17.0			6.1
291	2	4-12	2.68	4.14		7.8	21			.06											.08		27.0			7.6
292	3	12-22	1.84	3.12	8.0	7.1	19			.15											.12		22.4			11.0
293	4	22-34	.46	.70	8.5	7.4	21			.21											.72		20.0			6.9
294	5	34-60	.29	.44	7.8	7.5	21			2.47				7.81	39.6	79.2	6.3	43.8	3.47		2.8	1.07	25.0	4.3		5.2
295	RRS-3- 1	0-2	2.32	2.40	8.0	7.5	17			.15											.10		18.0			5.9
296	2	2-10	1.84	1.84	8.1	7.6	19			.16											.12		20.0			8.0
297	3	10-60	2.54	2.76	8.5	7.8	19			.16											.36		20.4			8.3
298	RRS-4- 1	0-5	3.54	1.37	8.1	7.7	22			.17											.20		35.0			9.1
299	2	5-30	.52	1.36	8.1	7.6	25			.34											1.1		32.4			12.8
300	3	30-48	4.78	.96	7.9	7.8	20			.94				7.31	32.0	67.8	5.5	29.9	2.03		1.2	.24	7.2	3.3		3.1

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

TABLE C1 continued

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
301	RRS-6-1	0-5	.88	1.18	8.2	7.2	18			.14											.12		26.0			8.7
302	2	5-50	.90	1.36	7.7	7.4	21			.45				2.92	.50	40.4	.11	41.5	1.68		.10	.08	33.0	.24		2.5
303	3	50-60	1.26	1.40	7.7	7.5	22			.81				4.09	.38	67.0	.07	47.1	3.16		.10	.08	56.0	.14		2.4
304	RRS-8-1	0-24	.40	.52	8.1	7.5	19			.17											.06		17.0			2.1
305	2	24-60	.31	.38	8.3	7.7	22			.18											.20		27.0			4.2
306	RRS-9-1	0-60	5.48	1.12	8.2	7.7	16			.13											.04		8.2			
307	RRS-10-1	0-4	5.56	3.12	8.1	7.7	19			.15											.04		22.4			0.7
308	2	4+	8.48	4.00	8.5	7.8	19			.13											.24		24.0			2.0

SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
William B. Peters, Luvern L. Resler, and Robert Vader 1/

Soil is characterized by laboratory methods to confirm judgment in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is

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to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be give to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable catio status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "look-out" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio [Richards, 1954].

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase I of the scheme, all samples would be characterized for (1) soil structure stability through measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, <u>selected</u> samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, <u>selected</u> samples suspected through the testing results of Phases I and II to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase I to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calci plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases I, II, and IV to be saline acid would be characterized for solub aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

Carbonate and bicarbonate were determined in saturation extract by titration with a weak acid solution and chloride was determined in saturation extract by Mohr volumetric method (Bower, C. A. and L. V. Wilcox, 1965. Soluble Salts. In C. A. Black, et al., Methods of Soil Analysis, Agronomy No. 9, American Society of Agronomy, 62-1.3.2.1, 62-3.4.2, and 62-3.5.2).

Cation-exchange capacity was measured at pH 8.2 by sodium saturation, washing with isopropyl alcohol, and extraction with ammonium acetate (Chapman, H. D., 1965. Cation Exchange Capacity. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 57-3).

Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Agricultural Handbook No. 60, 22c:104).

Hydraulic conductivity was measured on fragmented samples in plastic permeameters of 1-inch inside diameter under conditions of 2:1 constant head (USDI Bureau of Reclamation Instructions, 517.7.3).

Soil pH in 1:5 soil-water ratio suspension was measured by glass electrode and transistor voltmeter (Peech, Michael, 1965. Soil pH by Glass Electrode pH Meter. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 60-3.4.

Neutral salt exchange acidity and exchangeable aluminum were determined by extraction with 1N KCl and double titration with strong base and strong acid, respectively (McLean, E. O., 1965. Aluminum. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 67-3.2, 67-3.5).

Particle-size analysis was by the sieve and pipette method without removal of organic matter and insoluble carbonates using sodium metaphosphate for attaining dispersion (Day, Paul R., 1965. Particle Fractionation and Particle-Size Analysis. In C. A. Black, et al., Methods of Soil Analysis, Part 1, Agronomy No. 9, American Society of Agronomy, 43-4.3.1, 43-4.3.3, 43-4.3.5, and 43-4.3.6).

Soil pH in 1:2 soil 0.01M $CaCl_2$ solution ratio was measured by glass electrode and transistor voltmeter (Peech, Michael, 1965. Soil pH by Glass Electrode pH Meters. In C. A. Black, et al., Methods of Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 60-3.5).

Soluble salts were estimated by measuring electrical conductivity of saturation extract (Bower, C. A. and L. V. Wilcox, 1965. Soluble Salts. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 62-1.3.2.1 and 62-2.2).

Water retentivity of soil was measured at 15 bars pressure using ceramic plate or plastic membrane (Richards, L. A., 1965. Physical Condition of Water in Soil. In C. A. Black, et al., Methods of Soil Analysis, Part 1, Agronomy No. 9, American Society of Agronomy, 8-2.3).

RESULTS IN GREENHOUSE STUDIES

CHARACTERIZATION OF STRATA OVERLYING COAL SEAMS AS PLANT GROWTH MEDIA

This greenhouse study* was carried out in cooperation with and supplements ongoing work of the U.S. Bureau of Reclamation and the U.S. Bureau of Land Management.

Contract 6-07-DR-50310 U.S. Bureau of Reclamation

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* Only excerpts from this study which pertain to the Red Rim study area are presented.

ABSTRACT

Western wheatgrass was grown on overburden samples from six potential federal coal lease sites:

1. Bear Creek, Montana
2. Horse Nose Butte, North Dakota
3. Red Rim, Wyoming
4. Bisti West, New Mexico
5. Foidel Creek, Colorado
6. White Tail Butte, Wyoming

These samples included soil profile samples and geologic samples from core holes drilled by the U.S. Bureau of Reclamation. In this greenhouse study, 2.0 kg of each overburden sample was weighed into two pots and the samples were fertilized with 100 ppm nitrogen and 80 ppm phosphorus.

Large differences in yield were found among overburden and soil samples from all six sites. Yields ranged from 0.01 g to 4.65 g/pot. Relative yields were calculated as percentage of the yield of the standard soil (Platner series). Relative yields below 33% were considered low, between 33 and 67% medium, and above 67% high. The percentage of geologic and soil samples in each range were:

	Geologic	Soils
Low	26%	20%
Medium	52%	51%
High	22%	29%

Textures of the overburden ranged from very coarse to very fine, pH values ranged from 3.3 to 10.1, and electrical conductivities ranged up to 21 mmhos/cm.

ACKNOWLEDGEMENTS

The help of Gary Browning, CSU undergraduate, and Kathryn Beaumont, research technician, in carrying out the greenhouse work is greatly appreciated. The help of Lori Nukaya, secretary, in completing this report is also appreciated. Special thanks goes to the U.S. Bureau of Reclamation for funding the project and chemical

INTRODUCTION

In the past, surface mining for coal generally resulted in burying of the soil and then attempts were made to revegetate the spoil. The spoil left exposed was usually from the stratum directly overlying the coal seam and often was not a suitable plant growth medium.

It is visualized that in future surface mining operations, the soil will be conserved and replaced. However, on some sites the soil will be thin or less suitable as a plant growth medium than spoil generated from certain overburden strata. The objective of this study was to evaluate the suitability of overburden as plant growth media.

This greenhouse study was a portion of a larger study carried out by the Bureau of Reclamation in coring and characterizing overburden on potential federal coal lease sites. This report is on the Bear Creek, Horse Nose Butte, Red Rim, Bisti West, Foidel Creek, and White Tail Butte EMRIA sites. A previous report was on the Alton, Hanna Basin, Otter Creek, and Taylor Creek EMRIA sites.

Field Capacity

The initial task in the greenhouse study was to determine the field capacity of the overburden samples. The equipment used to determine field capacity was: plastic tubes 1 3/4 inches in diameter, plastic cups, and plastic sheets. Four hundred grams of each overburden sample was weighed and placed in the plastic cylinders which had been sealed at the bottom by a plastic sheet, and packed by tapping the side of the cylinder. Twenty milliliters of water was then added (5% of the overburden by weight) and the top was sealed with a plastic sheet. After 24 hours, the bottom plastic sheet was removed and the dry overburden fell into the plastic cup, leaving the moist overburden in the cylinder. The dry overburden was weighed and the field capacity (FC) calculated by the following equation:

$$FC = \frac{20 \text{ g } H_2O}{400 \text{ g - Weight of dry overburden}} \times 100$$

The field capacity percentage was the basis for the amount of water each pot received daily.

Fertilizer Treatments

Two thousand grams of each overburden and soil sample were weighed into each of two pots. Each pot was fertilized with 100 ppm of nitrogen as reagent grade $Ca(NO_3)_2$ and 80 ppm phosphorus as reagent grade $Ca(H_2PO_4)_2 \cdot H_2O$. The reagents were added in solution as 10 and 50 ml aliquots respectively, then mixed into the soils and overburden. Where sufficient soil material was not available for a

2 kg sample weights, the aliquot sizes were adjusted to maintain a fertility level of 100 ppm N and 80 ppm P.

Seeding and Growth

Western wheatgrass (*Agropyron smithii* var. Arriba) was the test species. This species was chosen because it is one of the most abundant native grasses in the Western United States and will probably be used in many revegetation programs.

At the time of seeding, approximately 250 g of overburden was removed from each pot. Then water was added to each pot to bring them to field capacity. Forty seeds were placed in each pot and the previously removed dry overburden placed on the seeds. All pots were then covered with paper to retard evaporation and to allow the water to move to the surface by capillary rise. The pots were checked daily and upon germination, each pot was uncovered and the date recorded. The date when ten plants had emerged and the severity of salt crusting were also recorded. After germination, all pots were weighed daily and deionized water was added to bring the soil to field capacity. Maximum water use was approximately 25% of field capacity per day.

When the majority of the plants, in all pots, reached a height of 10 cm, the number of plants in each pot was recorded and each pot was thinned to 16 plants.

Two highly productive loam soils were included in each experiment as overall standards (A_1 horizon Platner series and A_1 horizon Kimm series). In Table 1 through 6 greenhouse data on the standard soils is included at the end of each table.

Plants were harvested at approximately the same growth stage on all experiments. Because of growing conditions, the growth period varies for each experiment. Western wheatgrass was grown for 62 days following seeding, on the overburden from the Bear Creek site, Montana (September 28 to November 29, 1975), for 56 days on the samples from the Horse Nose Butte site, North Dakota and the Red Rim site, Wyoming (January 17 to March 13, 1976), for 49 days on the overburden from the Bisit West, New Mexico and Foidel Creek, Colorado sites (April 10 to May 29, 1976), and for 59 days on the overburden samples from the White Tail Butte site, Wyoming (September 16 to November 14, 1976).

Harvesting

The plants were clipped at a height of 2 cm above the soil surface to minimize contamination by soil splashed on the plants during watering. The harvested plants were then washed in 0.05 normal HCl and rinsed in distilled water so tissue analysis could be done on the plant samples. The plants were dried in a forced air oven at 70° C for 24 hours and then weighed to the nearest 0.01 gram.

Observations taken at the time of harvest included (1) the presence of shoot growth from rhizomes; (2) the degree of soil surface cracking; (3) the amount of salt crusting; and (4) the average plant height.

In comparing average plant height and plant dry weight it can be seen that there is no direct correlation. These differences are believed to be partially due to variation in light response in different seasons. Also, within experiments, a portion of the variation appears to be related to the amount of shoot growth originating from rhizomes, in that overburden samples with a low yield and tall average plant

height generally had very little or no growth from rhizomes while those samples with a high plant yield and a lower average plant height generally had a relatively large amount of growth from rhizomes. Also, the clayier samples generally had the largest amount of growth from rhizomes.

RESULTS

Large differences in Western wheatgrass growth are evident on various overburden samples (Figure below). Because there was a wide range on plant dry weights from the standard soils in the four greenhouse experiments, relative yields will be used in this discussion. Actual and relative yields are presented in pages C25 - C27. Relative yield was calculated as a percentage of yield of the Platner standard soil from the respective greenhouse experiments. For purposes of this discussion relative yields less than 33% will be considered low, 33-67% medium, and above 67% high.

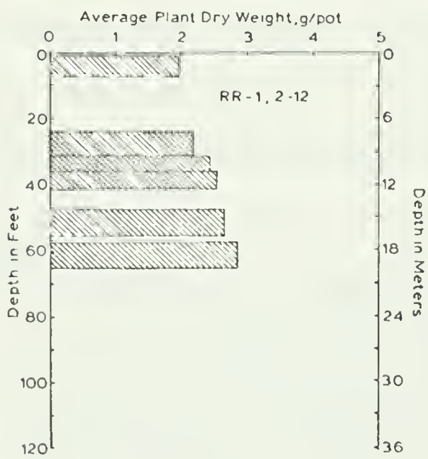
Figure Range in growth on samples from Red Rim site in Wyoming.

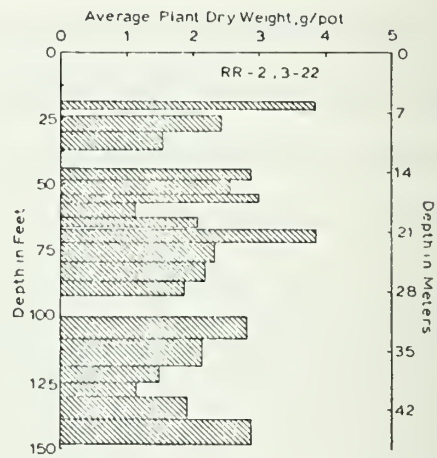
Figure Range in Western wheatgrass growth on overburden and soil samples from the Bear Creek, Horse Nose Butte, and Red Rim sites.

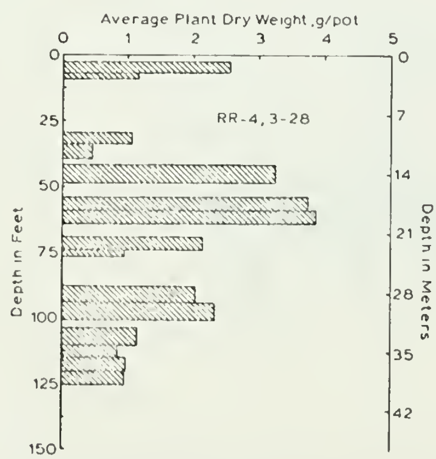
Red Rim, Wyoming (Fort Union formation)

Overburden samples from the Red Rim site, Wyoming, yielded 12% low, 50% medium, and 38% high (pages C 25-C27 and C30-C36). These samples had a wide variation in textures. The samples which yielded low generally showed salinity problems. Overall, the Red Rim overburden samples exhibited favorable characteristics as plant growth media.

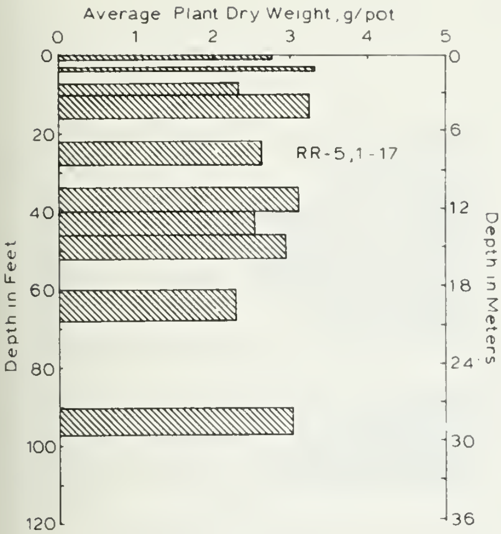
There were no soil profile samples from the Red Rim site used in the greenhouse trials.

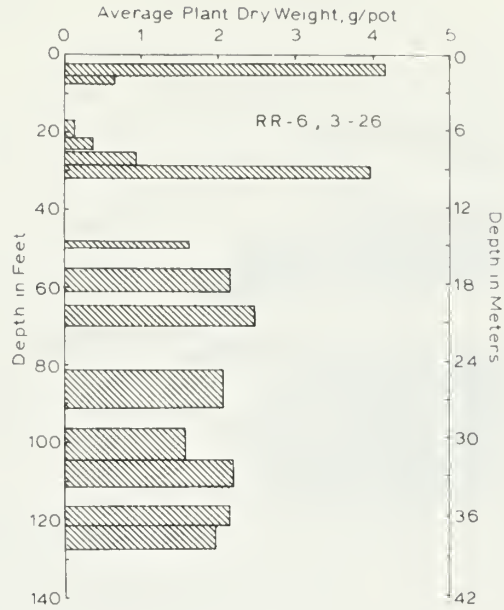


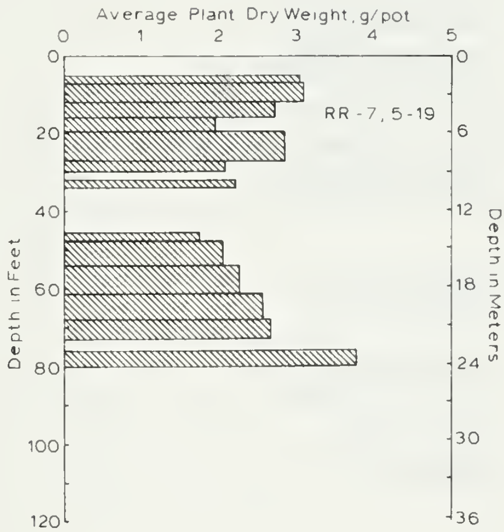




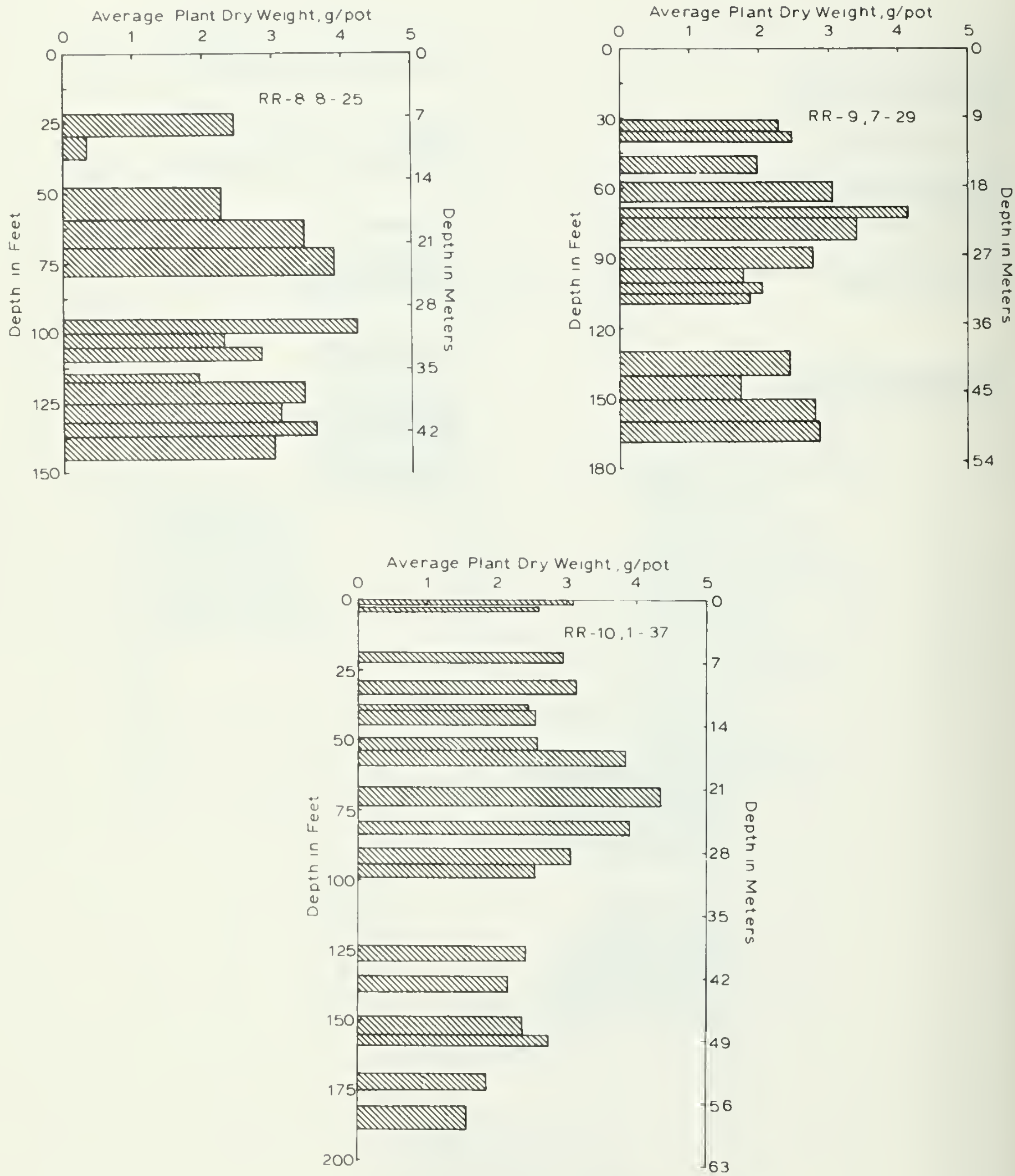
Yields of western wheatgrass on overburden samples from coreholes DH-1, DH-2, and DH-4, Red Rim site in Wyoming.







Yields of western wheatgrass on overburden samples from coreholes DH-5, DH-6, and DH-7, Red Rim site in Wyoming.



Yields of western wheatgrass on overburden samples from coreholes DH-8, DH-9, and DH-10, Red Rim site in Wyoming.

DISCUSSION

Large differences in yield were noted among overburden and soil samples from all six sites. Those overburden samples which had relative yields less than 33% would definitely not be suitable as plant growth media. The samples with relative yields larger than 33% include some strata which would make a favorable plant growth media, but also include some strata which would make unsuitable plant growth media under field conditions.

In the greenhouse study, overburden samples with the higher field capacities generally yielded the most. In the field, under arid and semi-arid conditions, these fine-textured materials would be the more drouthy soils becasue of greater surface runoff and evaporation. Thus, growth differences reported in this greenhouse study will give only an indication of the overburden suitability as a plant growth media. When extrapolating greenhouse results to field conditions, the physical and chemical characteristics of the overburden must be analyzed along with the greenhouse yield data to make interpretations on the suitability of the strata as a plant growth media.

Multiple regression analyses were run in an attempt to correlate yield with chemical and physical charateristics. For samples from one site, significant correlations were found but no significant correlations were found where all sites were included. This data will be included in a thesis on "Characterization of Overburden as a Plant Growth Media".

GREENHOUSE YIELDS AND OBSERVATIONS

The degree of surface cracking of the overburden were given a numerical designation as follows:

0 - none
1 - very slight
2 - slight
3 - moderate
4 - extreme

The degree of salt crusting was also observed and recorded as follows:

0 - no salt crust present
1 - 1-30% of surface area covered with salt crust
2 - 31-60% of surface area covered with salt crust
3 - 61-90% of surface area covered with salt crust
4 - 91-100% of surface area covered with salt crust

Blackened leaf tips were observed and frequency of occurrence, within pots, was recorded as follows:

0 - no plants with black leaf tips
1 - 1-4 plants with black leaf tips
2 - 5-8 plants with black leaf tips
3 - 9-12 plants with black leaf tips
4 - 13-16 plants with black leaf tips

These blackened leaf tips (5-10 mm) changed to a brown color after 1-2 weeks. Although the leaf tips died back, there was no evidence of overall yield reduction of plants so affected.

Roman numerals I and II in the following tables refer to replications. Duplicate pots were run on all soil and overburden samples for which there was adequate soil material.

Red Rim Greenhouse Data.

Sample No.	Depth(ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
RR- 1- 2	1.0 - 7.7	2	7	8	36	36	1	0	2.36	1.59	49	30	20	4	0	10.3
RR- 1- 6	24.0 - 31.4	2	7	*	39	*	1	0	2.19	*	58	30	*	4	0	11.8
RR- 1- 7	31.4 - 36.0	1.85	7	8	33	33	1	0	2.52	2.35	61	33	28	4	0	11.3
RR- 1- 8	36.0 - 41.4	2	8	*	40	*	0	0	2.42	2.67	64	31	23	4	0	11.6
RR- 1-10	47.0 - 55.5	2	9	*	35	*	0	0	2.67	*	67	34	*	3	0	14.2
RR- 1-12	57.0 - 65.0	2	8	*	39	*	1	0	2.85	*	71	33	*	4	1	12.6
RR- 2- 3	18.9 - 22.0	2	7	*	31	*	1	0	3.83	*	96	35	*	4	0	19.9
RR- 2- 5	24.0 - 30.0	2	8	10	31	30	1	3	2.41	2.45	60	35	24	4	1	18.7
RR- 2- 6	30.0 - 37.0	2	10	11	35	39	2	1	1.80	1.33	39	29	19	1	0	16.3
RR- 2- 7	44.0 - 48.0	2	8	8	39	38	2	1	2.69	3.08	72	32	28	1	1	17.6
RR- 2- 8	48.0 - 53.5	2	7	7	40	37	1	1	2.81	2.34	64	32	27	1	1	19.0
RR- 2- 9	53.5 - 57.0	2	8	8	36	30	1	0	3.33	2.66	75	36	24	2	1	17.6
RR- 2-10	57.0 - 62.5	2	8	8	34	33	0	1	1.16	1.11	28	23	21	4	0	9.8
RR- 2-11	62.5 - 66.0	1.9	10	9	34	29	1	0	1.85	2.33	52	30	25	1	0	14.6
RR- 2-12	67.0 - 72.0	1.95	7	7	37	40	1	1	3.39	4.40	97	34	22	2	2	17.4
RR- 2-13	72.0 - 78.4	2	8	7	32	39	0	0	2.14	2.50	58	30	22	2	0	12.9
RR- 2-14	78.4 - 86.0	2	7	7	36	33	1	1	2.05	2.35	55	29	25	3	0	11.5
RR- 2-15	86.0 - 92.0	2	7	7	36	35	1	0	1.95	1.83	47	28	24	3	0	11.7
RR- 2-17	100.0 - 108.9	2	8	8	30	16	0	0	3.05	2.57	70	34	26	3	0	22.2

* Sample enough for only one pot.

(cont.) Red Rim Greenhouse Data.

Sample No.	Depth(ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	Germination: Days After Seeding for Ten Plants to Emerge II	Germination: Number of Seeds Germinated I	Germination: Number of Seeds Germinated II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	Harvest: Plant Dry Weight (gm) II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	Harvest: Average Plant Height (cm) II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
RR- 2-18	108.9 - 118.9	2	7	7	37	36	2	1	1.97	2.32	54	29	23	1	0	11.9
RR- 2-19	118.9 - 125.0	2	9	8	37	38	2	2	1.45	1.55	38	25	20	3	0	12.2
RR- 2-20	125.0 - 128.0	2	8	8	37	39	1	1	1.44	0.89	29	22	17	0	0	11.3
RR- 2-21	128.0 - 138.9	1.9	8	8	33	38	2	0	2.07	1.81	49	29	22	1	0	12.1
RR- 2-22	138.9 - 147.9	1.95	7	7	34	39	1	0	2.89	2.91	73	29	24	2	0	11.0
RR- 4- 3	2.5 - 6.5	2	8	8	39	38	1	1	2.57	2.59	65	34	23	3	0	10.6
RR- 4- 4	6.5 - 8.0	2	7	*	35	*	0	0	1.19	*	30	24	*	3	0	9.2
RR- 4- 9	29.0 - 33.4	2	7	*	40	*	0	0	1.07	*	27	27	*	4	0	9.9
RR- 4-10	33.4 - 39.0	2	9	*	29	*	0	0	0.44	*	11	17	*	4	0	7.2
RR- 4-12	41.0 - 48.5	1.8	8	8	34	40	1	1	2.74	3.69	80	33	26	0	1	18.2
RR- 4-14	53.3 - 59.0	1.9	9	9	30	35	1	1	3.12	4.32	93	33	26	2	1	19.7
RR- 4-15	59.0 - 64.0	2	7	7	37	36	2	1	4.15	3.60	96	35	28	1	1	21.5
RR- 4-17	69.0 - 74.0	2	8	8	39	38	1	1	2.09	2.22	54	30	21	1	1	17.4
RR- 4-18	74.0 - 76.0	2	8	*	38	*	2	1	0.97	*	24	20	*	0	1	16.4
RR- 4-22	87.7 - 94.0	2	8	8	37	35	1	1	2.18	1.86	51	30	20	1	2	16.8
RR- 4-23	94.0 - 100.7	2	8	8	40	37	1	1	2.29	2.35	58	30	22	2	1	16.4
RR- 4-25	103.7 - 110.7	2	8	9	38	38	2	1	0.88	1.46	29	21	20	0	2	16.8
RR- 4-26	110.7 - 115.0	2	8	8	37	39	1	1	1.01	0.67	21	19	15	1	1	13.1
RR- 4-27	115.0 - 120.7	2	8	8	39	38	1	1	0.92	1.07	25	23	15	1	1	14.0

* Sample enough for only one pot.

(cont.) Red Rim Greenhouse Data.

Sample No.	Depth(ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
RR- 4-28	120.8 - 125.3	1.95	8	10	34	40	1	1	0.76	1.07	23	17	17	0	2	15.4
RR- 4-30	141.0 - 142.0	2	8	*	36	*	3	3	1.40	*	35	25	*	0	0	17.9
RR- 4-31	142.4 - 148.0	1.95	7	7	37	35	1	2	2.47	2.51	62	31	26	0	2	17.1
RR- 5- 1	0.0 - 1.0	2	7	*	36	*	1	1	2.78	*	70	34	*	3	1	17.8
RR- 5- 4	3.0 - 4.0	2	8	*	36	*	2	1	3.31	*	83	36	*	3	1	21.8
RR- 5- 6	7.0 - 10.0	2	8	7	37	39	1	0	2.12	2.53	58	32	20	4	0	13.2
RR- 5- 7	10.0 - 16.0	1.9	8	8	38	39	1	0	3.09	3.37	81	31	23	4	0	15.3
RR- 5- 9	22.0 - 28.0	2	7	7	39	37	1	0	2.93	2.29	65	34	20	4	0	14.7
RR- 5-11	34.0 - 40.0	1.9	7	7	39	36	0	0	3.13	3.07	78	32	30	4	0	16.8
RR- 5-12	40.0 - 46.0	1.85	7	7	36	35	0	0	2.68	2.42	64	33	24	3	0	13.8
RR- 5-13	46.0 - 52.0	1.9	7	6	38	40	1	0	3.14	2.71	73	34	25	2	0	14.9
RR- 5-15	60.0 - 68.0	1.9	8	8	35	38	0	0	2.39	2.22	58	31	25	3	0	12.1
RR- 5-17	90.7 - 97.4	2	7	8	39	37	1	1	3.38	2.69	76	31	26	3	2	16.3
RR- 6- 3	2.5 - 5.0	2	8	*	34	*	1	1	4.17	*	104	37	*	3	1	30.1
RR- 6- 4	5.0 - 7.5	2	9	*	35	*	0	2	0.67	*	17	27	*	2	0	21.4
RR- 6- 6	17.0 - 21.5	1.8	20	9	21	36	2	3	0.10	0.19	4	6	8	0	0	31.1
RR- 6- 7	21.5 - 24.5	2	9	*	33	*	3	2	0.39	*	10	12	*	0	0	31.4
RR- 6- 8	25.0 - 28.4	1.8	9	9	35	26	1	3	0.97	0.86	23	23	18	0	0	17.9

* Sample enough for only one pot.

. (cont.) Red Rim Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
RR- 6- 9	28.4 - 32.0	1.8	7	8	37	38	3	2	4.17	3.79	100	3[illegible]	24	0	1	23.5
RR- 6-13	48.1 - 50.0	2	9	11	36	37	1	1	1.57	1.66	40	23	19	1	1	10.5
RR- 6-15	55.2 - 61.3	2	7	8	32	35	0	1	2.39	1.90	54	34	22	3	0	11.8
RR- 6-17	64.8 - 70.0	1.9	7	7	35	37	1	0	2.59	2.33	62	32	25	2	0	11.0
RR- 6-20	81.5 - 91.5	1.8	7	7	36	36	0	0	2.39	1.71	51	28	23	3	0	9.6
RR- 6-22	96.5 - 104.5	2	8	9	39	38	1	1	1.53	1.60	39	27	18	1	1	16.3
RR- 6-23	104.5 - 111.5	1.95	7	8	39	39	1	0	2.16	2.20	55	28	23	2	1	17.7
RR- 6-25	116.5 - 121.5	1.9	8	8	33	37	1	1	1.79	2.47	53	26	22	1	0	19.1
RR- 6-26	121.5 - 127.5	1.95	7	9	36	35	1	1	2.07	1.81	49	30	24	1	1	11.9
RR- 7- 5	5.0 - 7.0	2	6	6	37	33	0	0	2.99	3.09	76	32	24	3	0	13.2
RR- 7- 6	7.0 - 12.0	2	7	7	36	40	1	0	2.75	3.45	78	31	23	3	0	13.6
RR- 7- 7	12.0 - 16.0	1.85	7	9	35	37	0	0	3.14	2.34	69	32	24	2	0	15.2
RR- 7- 8	16.0 - 19.5	2	7	6	35	40	1	0	1.18	2.76	49	37	23	2	0	15.3
RR- 7- 9	19.5 - 27.1	2	7	7	39	38	1	0	2.72	2.99	71	35	27	4	0	13.4
RR- 7-10	27.1 - 30.0	2	11	*	33	*	2	1	2.08	*	52	31	*	1	1	23.9
RR- 7-11	32.0 - 34.0	1.95	11	8	31	38	1	1	1.50	2.93	55	30	28	0	0	15.6
RR- 7-13	45.9 - 47.9	2	9	*	39	*	1	1	1.76	*	44	30	*	0	0	17.1
RR- 7-14	47.9 - 54.0	2	8	9	33	29	1	0	2.17	1.95	52	28	21	0	1	12.3
RR- 7-15	54.0 - 61.0	2	7	7	37	39	1	1	2.61	1.98	57	30	20	0	0	12.1

* Sample enough for only one pot.

(cont.) Red Rim Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
RR- 7-16	61.0 - 68.0	1.95	8	8	40	35	1	1	2.30	2.83	35	31	22	1	0	12.2
RR- 7-17	68.0 - 73.0	2	6	*	37	*	0	1	2.69	*	67	34	*	1	0	13.5
RR- 7-19	76.0 - 80.0	1.8	7	7	37	38	1	0	3.86	3.68	94	34	31	1	0	16.8
RR- 8- 8	21.0 - 29.0	2	8	9	39	35	1	1	2.36	2.59	62	31	19	1	1	16.6
RR- 8- 9	29.0 - 37.6	2	13	11	28	33	1	2	0.29	0.35	8	9	10	1	1	10.8
RR- 8-11	48.0 - 59.0	2	8	8	37	39	0	1	2.39	2.13	57	29	25	4	0	8.2
RR- 8-12	59.0 - 69.0	2	7	7	38	39	0	0	3.63	3.30	87	34	23	3	0	16.5
RR- 8-13	69.0 - 79.4	2	6	6	38	39	0	0	4.04	3.76	98	37	27	3	0	16.5
RR- 8-17	95.0 - 100.0	2	6	6	40	40	0	0	3.87	4.57	106	39	25	2	0	17.3
RR- 8-18	100.0 - 105.0	2	7	6	37	40	0	0	2.48	2.13	58	30	18	3	0	15.2
RR- 8-19	105.0 - 110.0	2	7	7	39	40	0	1	3.44	2.31	72	36	23	2	0	18.3
RR- 8-21	114.6 - 117.4	2	8	8	35	31	1	1	1.94	1.97	49	30	21	1	2	17.4
RR- 8-22	117.4 - 125.0	2	6	7	36	36	0	0	3.80	3.19	87	35	24	3	0	16.7
RR- 8-23	125.0 - 132.0	2	7	7	37	38	0	0	3.13	3.15	79	35	24	2	0	18.1
RR- 8-24	132.0 - 137.0	1.95	7	7	39	38	0	0	3.53	3.71	91	35	24	2	0	18.7
RR- 8-25	137.0 - 145.0	1.95	6	6	36	38	0	0	2.86	3.17	75	32	21	2	0	17.5
RR- 9- 7	31.5 - 35.0	2	8	7	35	40	0	0	2.16	2.39	57	29	28	2	0	11.5
RR- 9-10	37.5 - 41.3	2	8	7	39	37	1	0	2.40	2.52	62	31	21	2	1	15.2

* Sample enough for only one pot.

. (cont.) Red Rim Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
RR-10-12	53.0 - 58.3	2	6	6	38	38	0	0	4.02	3.71	97	35	30	2	0	21.2
RR-10-16	68.3 - 73.3	2	7	8	40	30	1	1	4.61	4.08	109	36	31	2	1	22.5
RR-10-18	78.3 - 83.3	1.95	6	6	37	36	1	1	4.27	3.55	98	36	29	3	0	19.4
RR-10-20	88.3 - 93.3	2	7	7	33	39	1	0	3.34	2.78	77	36	23	1	1	18.2
RR-10-21	93.3 - 98.3	2	8	8	36	33	1	1	2.75	2.34	64	32	25	1	1	19.4
RR-10-26	123.0 - 128.3	2	7	7	37	38	0	0	2.60	2.23	60	30	24	4	0	11.8
RR-10-28	134.5 - 140.0	2	8	7	37	40	1	0	2.37	2.01	55	30	21	2	1	17.4
RR-10-31	148.5 - 155.5	2	7	7	36	38	0	0	2.30	2.44	59	29	21	2	0	11.0
RR-10-32	155.5 - 158.3	2	7	6	37	37	0	0	2.65	2.85	69	32	22	2	0	16.5
RR-10-35	168.3 - 175.0	2	7	7	37	40	0	0	2.04	1.68	47	27	27	2	0	10.7
RR-10-37	181.0 - 188.3	1.9	7	7	39	38	1	1	2.44	2.69	64	30	25	3	0	12.4
STANDARD SOILS																
R-438-26																
Control	surface	2	7	8	35	36	0	0	2.22	2.62	61	28	21	0	1	16.1
Platner	surface	2	6	6	38	37	0	0	4.27	3.71	100	32	22	0	0	15.2
Red Rim																
Check	surface	2	7	7	37	38	0	0	3.84	4.15	100	35	25	1	0	18.4
Kimm	surface	2	6	6	35	40	0	0	4.71	4.47	115	37	38	0	0	20.6

(cont.) Red Rim Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
RR- 9-12	46.0 - 53.7	2	8	8	37	35	1	1	1.87	2.11	50	19	19	0	2	16.5
RR- 9-13	57.5 - 65.8	2	7	8	40	37	1	0	2.99	3.15	77	37	21	1	1	16.5
RR- 9-15	67.3 - 72.7	2	7	6	38	37	1	0*	3.84	4.40	103	36	30	1	0	22.5
RR- 9-16	72.7 - 82.2	2	7	7	37	39	2	1	3.34	3.47	85	34	32	1	1	20.0
RR- 9-17	85.7 - 94.0	2	7	8	33	30	1	0	2.86	2.69	69	37	23	1	1	15.6
RR- 9-18	94.0 - 100.2	2	9	10	37	37	0	0	1.72	1.86	45	30	24	1	2	15.8
RR- 9-19	100.2 - 105.0	2	8	8	37	37	2	1	1.96	2.14	51	30	19	0	1	18.0
RR- 9-20	105.0 - 109.5	2	9	7	36	39	1	0	1.73	1.99	47	23	21	2	0	12.0
RR- 9-24	130.0 - 140.0	2	9	9	36	36	1	0	2.00	2.84	61	29	23	3	1	15.5
RR- 9-25	140.0 - 150.2	2	8	9	37	38	1	1	1.80	1.68	44	25	22	2	0	10.2
RR- 9-26	150.2 - 160.2	2	7	6	39	39	0	0	2.63	2.98	70	30	24	4	0	12.0
RR- 9-27	160.2 - 168.7	1.95	7	7	35	39	1	0	2.48	3.20	71	27	26	2	0	12.1
RR-10- 1	0.0 - 1.0	2	6	6	35	39	0	0	3.34	2.85	77	35	20	4	0	14.7
RR-10- 3	2.5 - 3.5	2	7	7	38	39	0	0	2.59	2.60	65	33	21	2	0	13.8
RR-10- 4	18.3 - 22.3	1.85	6	6	39	37	1	0	3.27	2.64	74	34	24	3	0	14.5
RR-10- 6	28.3 - 33.5	1.9	7	7	36	38	1	0	3.23	3.04	78	31	25	2	0	15.3
RR-10- 8	37.5 - 39.0	2	7	6	36	38	1	1	2.64	2.26	61	33	23	2	0	19.8
RR-10- 9	39.0 - 44.0	2	6	6	38	37	1	0	2.63	2.47	64	33	22	3	0	13.5
RR-10-11	48.3 - 53.0	2	7	7	39	35	0	0	2.71	2.48	65	34	20	2	0	15.9

* Sample enough for only one pot.

WEATHERING TESTS CONDUCTED ON CORE SAMPLES

Objectives

Laboratory weathering tests were conducted on overburden core samples from the four sites listed below to determine which materials would break down sufficiently to allow for their possible use as a planting media in revegetation of strip mined areas. The site and number of core samples tested under each condition are as follows:

Site	Number of samples tested: Freeze-thaw	Wet-dry	Outdoor
Red Rim, Wyoming	9	9	9
Bear Creek, Montana	11	11	11
Horse Nose Butte, North Dakota	9	9	7
Bisti West, New Mexico	21	21	21

Results of laboratory weathering tests conducted on core samples from four other sites were reported previously in Applied Science Referral Memorandum No. 75-1-2, dated March 28, 1975.

Test Procedures

Specimens for the freeze-thaw, wet-dry, and outdoor tests were cut from core samples submitted by regional personnel. The purpose of including outdoor exposure tests was to determine if any correlation could be drawn between this type of weathering and the freeze-thaw and wet-dry conditions.

A freeze-thaw cycle consisted of the following conditions: (1) eight hours at 23.9°C (75°F), 100 percent relative humidity (wetting/thawing) and (2) sixteen hours (64 hours on weekend) at -17.8°C (0°F) (freezing).

For the wet-dry tests, one cycle consisted of: (1) eight hours at 23.9°C (75°F), 100 percent relative humidity (wetting) and (2) sixteen hours (64 hours on weekends) at 37.8°C (100°F), 10 percent relative humidity (drying).

Except for samples from Red Rim, core specimens about 5 cm (2 inches) in diameter by 5 cm (2 inches) in length were used. The core specimens from Red Rim were 10.2 cm (4 inches) in diameter by 2.5 cm (1 inch) in length. For testing and handling, the smaller core specimens were placed on a No. 10 mesh screen in 400-ml plastic beakers. The Red Rim specimens were placed in 1-quart waxed cardboard containers.

Tests were started on December 23, 1975, and 43 laboratory weathering cycles were completed on March 1, 1976. For the outdoor exposure specimens, 10 weeks of testing were completed on March 2, 1976. During this 10-week period, the specimens were subjected to approximately

2.5 cm (1 inch) of precipitation from about seven snowstorms. Also, it is estimated that from 40 to 50 freeze-thaw cycles occurred during this period. For example, during January the temperature range for freeze-thaw occurred on 26 of 31 days.

The test specimens were visually examined about once a week to monitor changes. Also, to provide a visual record of the tests, photographs (both black and white, and 35-mm color slides) were taken before and after testing on 11 core samples representing various soil types.

Illustrated in pages 41-42 are several of the terms listed under the remarks column in the tables to describe the various breakdown patterns noted during testing. Further, the term "saturated" as used in this report denotes the condition in which free water was observed on the surface of the specimen (figure 1c). The term "swelling" was used when an increase in specimen size was noted (figure 1c). Quite often this swelling resulted in a mushroom appearance.

At the completion of the 43 weathering cycles, a percent breakdown value (%BD) was determined for a number of the specimens. This value listed under the remark column in the tables was derived as follows:

$$\%BD = \frac{TW-IW}{TW} = 100$$

Where: TW = Total specimen weight
IW = Weight of original specimen remaining intact after testing

In the freeze-thaw tests, the specimens were not allowed to dry out, and the continual wetting caused the specimens to become saturated, this resulted, in many cases, in breakdown or swelling. For these specimens the %BD was considered to be 100.

For future laboratory weathering tests it is recommended that the samples be subjected to alternate freeze-thaw and wet-dry cycles. This would eliminate the continual wetting process for the freeze-thaw specimens, and it would simulate more closely, the outdoor weathering as observed in this study.

The outdoor specimens will continue to be monitored, and a subsequent report will be prepared summarizing the results. Test results for samples from the Red Rim area are discussed in the following paragraphs.

Test Results

Test results are summarized in table RR-1 and figures RR-1 and RR-2.

Three sandstone samples exhibited no breakdown at all. These included RR-2-16 (depth 92.0 to 100.0 feet) RR-7-18 (depth 73.0 to 76.0 feet) and RR-10-37 (depth 181.0 to 188.3 feet).

The following samples appeared to have broken down sufficiently for possible use as a planting media: siltstone, RR-2-9 (depth 53.5 to 57.0 feet) siltstone, RR-9-17 (depth 85.7 to 94.0 feet) and sandstone, RR-10-9 (depth 39.0 to 44.0 feet).

It should be noted that the use of a diamond saw was required to cut the test specimens from the submitted core samples, and is indicative of their original condition.

A dry gradation analysis was obtained on two freeze-thaw specimens and the results are listed below:

Sandstone, RR-7-16
Depth 61.0 to 68.0 feet

Sieve size	Cumulative percent passing
4	100.0
10	99.8
50	82.1
100	12.7
200	6.6

Sandstone, RR-10-9
Depth 39.0 to 44.0 feet

Sieve size	Cumulative percent passing
4	100.0
10	99.7
50	36.8
100	8.2
200	3.3

Table RR-1

Siltstone, RR-2-9* Depth 53.5 - 57.0 feet (RR-1)**	Freeze-thaw: Slaking at 6 cycles saturated at 15 cycles, %BD = 100 feet. Wet-dry: No change. Outdoor: Cracking and slaking at 10 weeks.
Sandstone, RR-2-16 Depth 92.0 - 100.0 feet (RR-2)	Freeze-thaw: No change. Wet-dry: No change. Outdoor: No change at 10 weeks.
Shale, RR-4-23 Depth 94.0 - 100.7 feet (RR-3)	Freeze-thaw: Cracking at 25 cycles, slaking on one side at 35 cycles. %BD = 11.5. Wet-dry: No change. Outdoor: No change at 10 weeks.
Sandstone, RR-7-16 Depth 61.0 - 68.0 feet (RR-4)	Freeze-thaw: Saturated at 15 cycles. %BD = 100. Wet-dry: No change. Outdoor: Very slight surface erosion at 4 weeks.
Sandstone, RR-7-18 Depth 73.0 - 76.0 feet (RR-5)	Freeze-thaw: No change. Wet-dry: No change. Outdoor: No change at 10 weeks.
Siltstone, RR-9-17 Depth 85.7 - 94.0 feet (RR-6)	(See photograph RR-1) Freeze-thaw: Cracking at 12 cycles, saturated at 15 cycles. %BD = 100. Wet-dry: Slight cracking noted originally. cracking increased slightly at 43 cycles. Outdoor: Cracking at 2 weeks, slaking at 4 weeks, slaking continuing at 10 weeks, this sample has exhibited more breakdown than wet-dry sample.
Siltstone, RR-9-25 Depth 140.0 - 150.2 feet (RR-7)	Freeze-thaw: Slight cracking at 6 cycles, saturated at 15 cycles. %BD = 100. Wet-dry: No change. Outdoor: Cracking and slight slaking at 2 weeks, slaking continuing at 10 weeks, this sample has exhibited more breakdown than wet-dry sample.
Sandstone, RR-10-9 Depth 29.0 - 44.0 feet (RR-8)	(See photograph RR-2) Freeze-thaw: Cracking at 20 cycles, sample very friable at 25 cycles, %BD = 100. Wet-dry: No change. Outdoor: Slight cracking at 2 weeks, sample friable at 10 weeks, this sample has exhibited more breakdown than wet-dry sample.
Sandstone, RR-10-37 Depth 181.0 - 188.3 feet (RR-9)	Freeze-thaw: No change. Wet-dry: No change. Outdoor: No change at 10 weeks.

* Field sample number.
** Laboratory sample number.

a. Cracking,peeling (left); cracking (right).

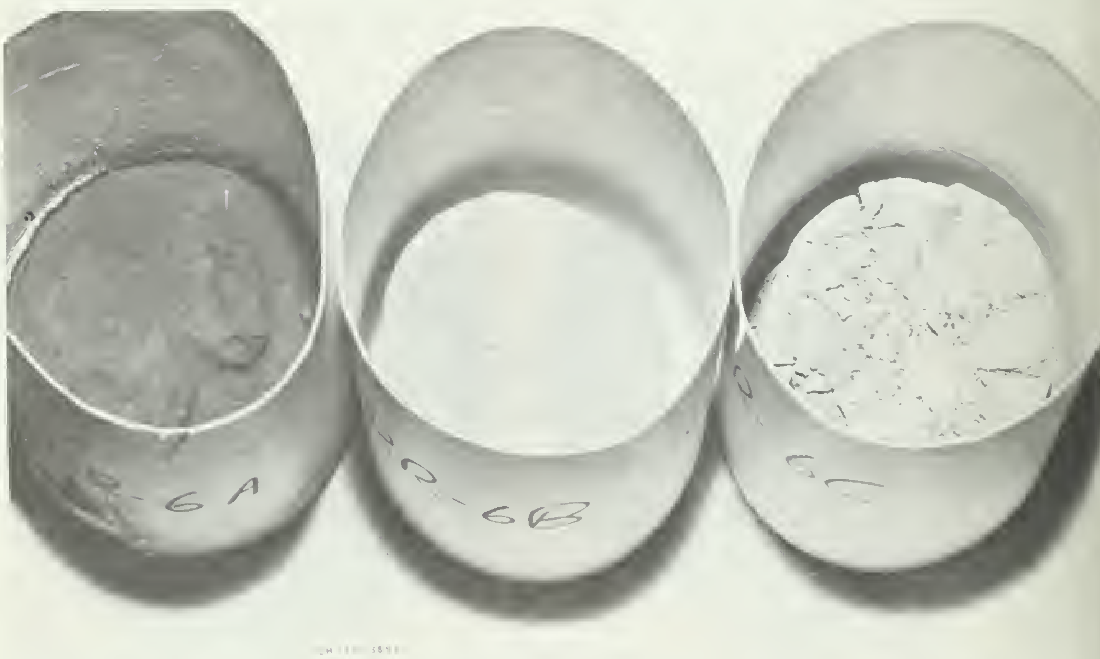
b. Cleaving (left); slaking (right).

Examples of typical distress patterns noted du-ing laboratory weathering tests.

c. Saturated (left); swelling (right)

Examples of typical distress patterns noted during laboratory weathering tests.
(continued)

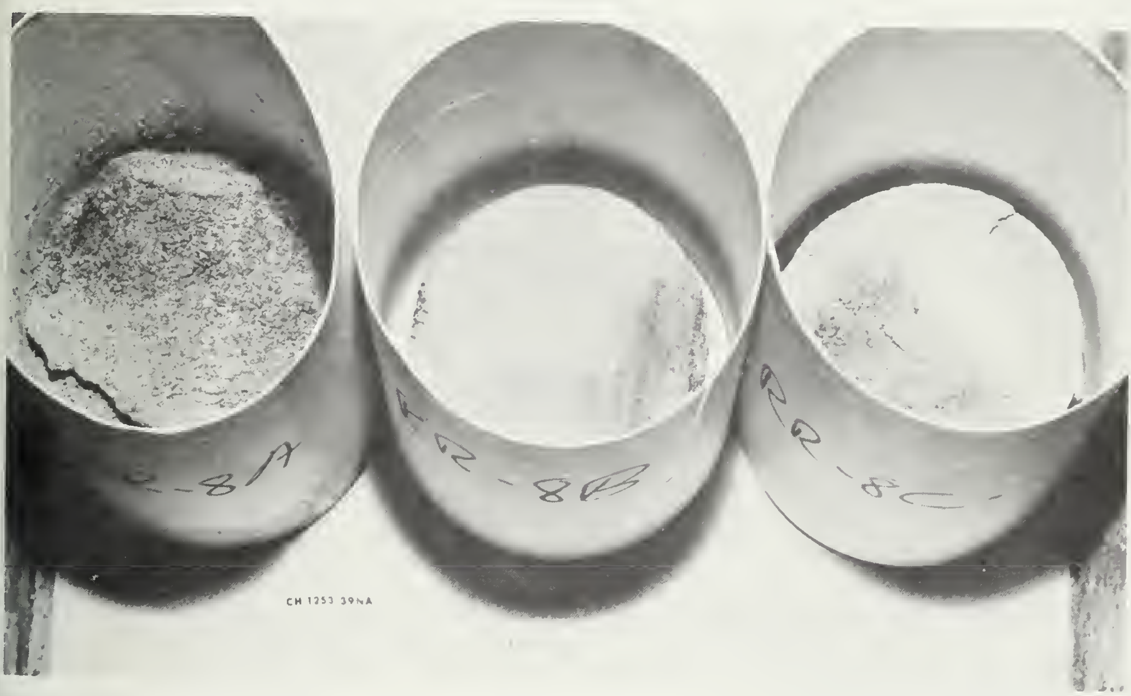
a. Original condition.



b. Condition after 43 weathering cycles for A and B,
and 10 weeks of outdoor exposure for C.

Figure RR-1. Results of laboratory weathering for siltstone sample from Red Rim, Wyoming; RR 9-17, depth 85.7' to 94.0'. Sample A on left was subjected to freeze-thaw; Sample B in center was subjected to wet-dry; and Sample C on right was subjected to outdoor weathering.

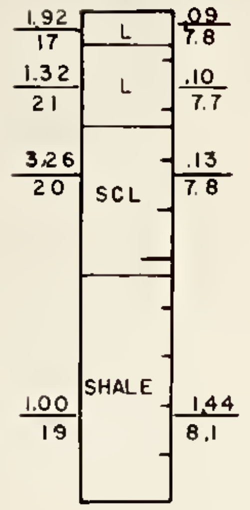
a. Original condition.



b. Condition after 43 weathering cycles for A and B, and 10 weeks of outdoor exposure for C.

Figure RR-2. Results of laboratory weathering for sandstone sample from Red Rim, Wyoming; RR 10-9, depth 39.0' to 44.0'.

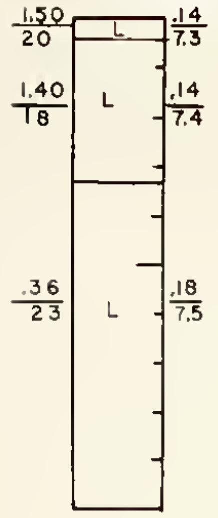
NO. 18-1



LOCATION: 300' SOUTH 500' WEST OF SE CORNER OF SE$\frac{1}{4}$ NW$\frac{1}{4}$

PM: CALCAROUS SOFT SHALE AND SILTSTONE

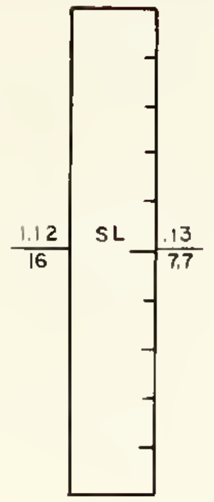
NO. 18-4



LOCATION: 600' SOUTH 250' WEST OF NE CORNER OF NW$\frac{1}{4}$ SE$\frac{1}{4}$

PM: VALLEY FILL

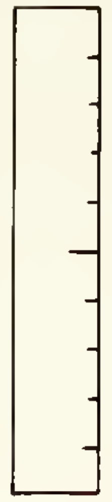
NO. DH-9



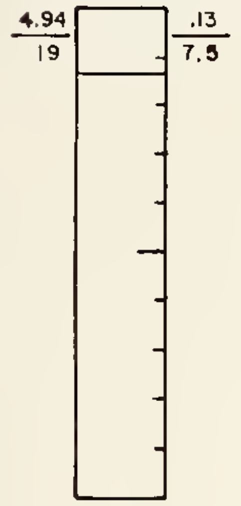
LOCATION: 200' NORTH 400' EAST OF SW CORNER OF NW$\frac{1}{4}$ NE$\frac{1}{4}$

PM: SOFT WEATHERED SANDY SHALE

NO.



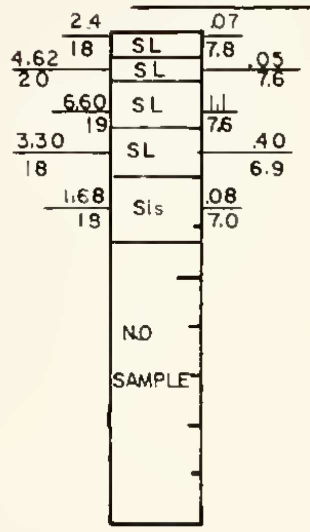
NO. 18-2



LOCATION: 180' NORTH 450' EAST OF SW CORNER OF SW$\frac{1}{4}$ SW$\frac{1}{4}$

PM: SANDSTONE

NO. 18-5

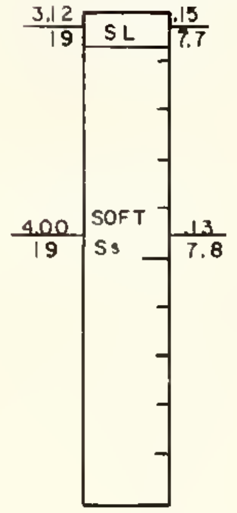


LOCATION: 50' NORTH 500' EAST OF SW CORNER OF NE$\frac{1}{4}$ NE$\frac{1}{4}$

PM: SOFT SANDSTONE

REMARKS: ROUGH AND BROKEN TOPOGRAPHY GENERALLY EXCEEDS 25% SLOPE

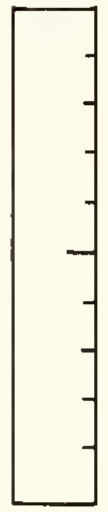
NO. DH-10



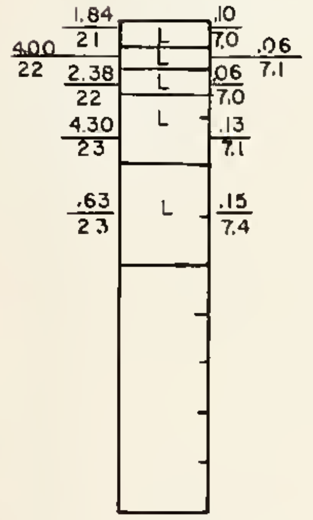
LOCATION: 600' SOUTH 500' WEST OF NE CORNER OF SE$\frac{1}{4}$ SE$\frac{1}{4}$

PM: MIXED SANDSTONE AND SHALE

NO.



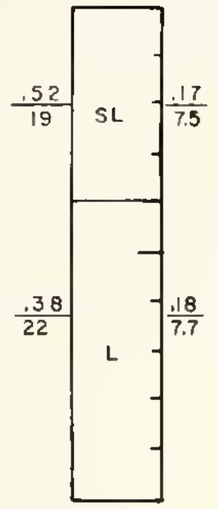
NO. 18-3



LOCATION: 300' NORTH 50' EAST OF SW CORNER OF SE$\frac{1}{4}$ SW$\frac{1}{4}$

PM: SANDSTONE

NO. DH-8

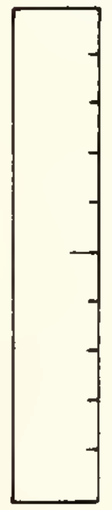


LOCATION: 300' SOUTH 250' WEST OF NE CORNER OF NE$\frac{1}{4}$ NE$\frac{1}{4}$

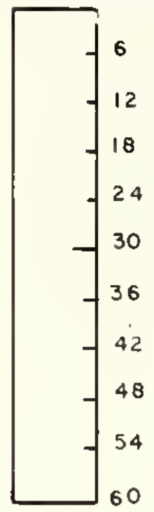
PM: VALLEY FILL

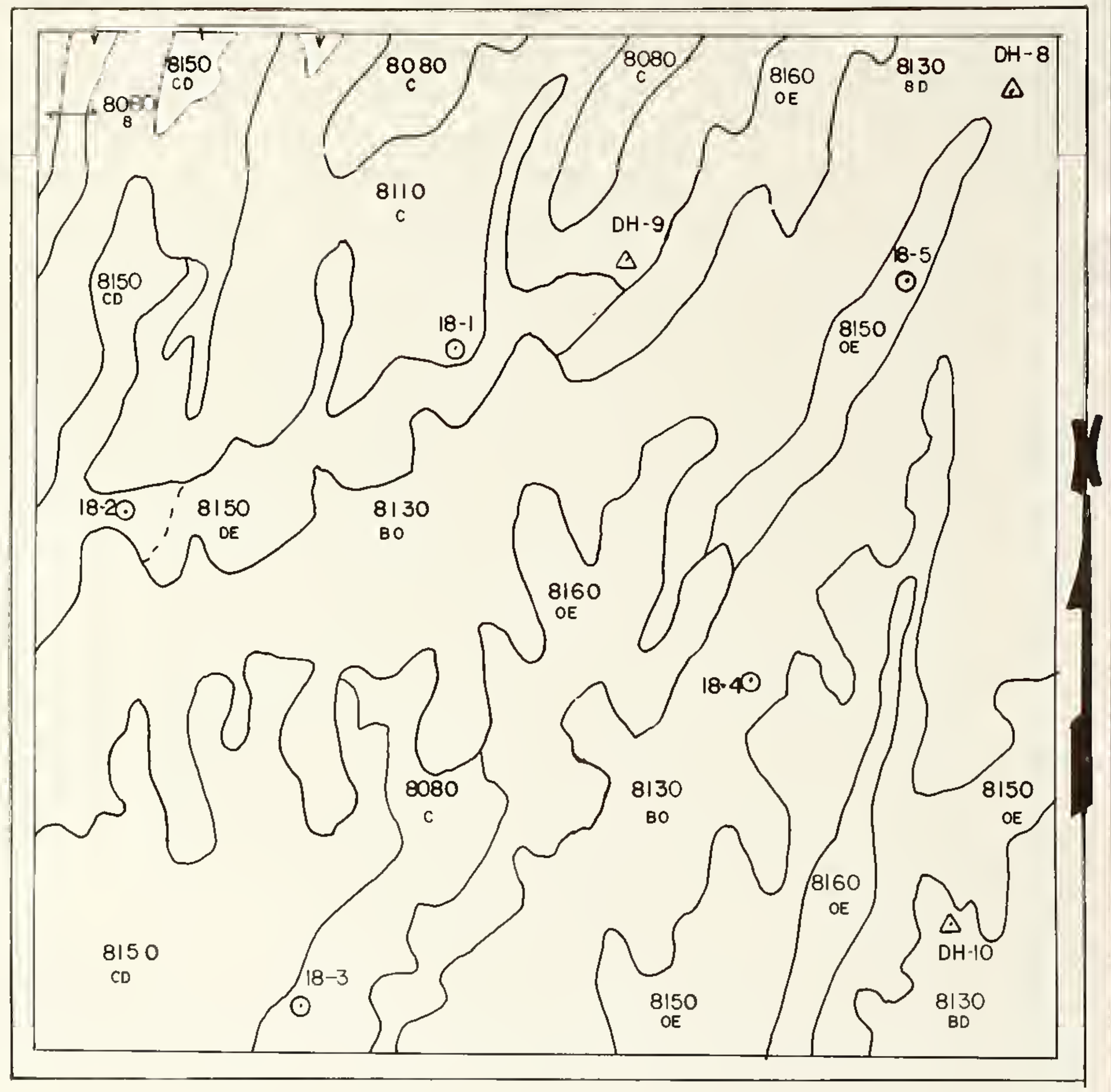
REMARKS: SOIL AGGREGATION POORLY DEFINED

NO.



NO. DEPTH IN INCHES

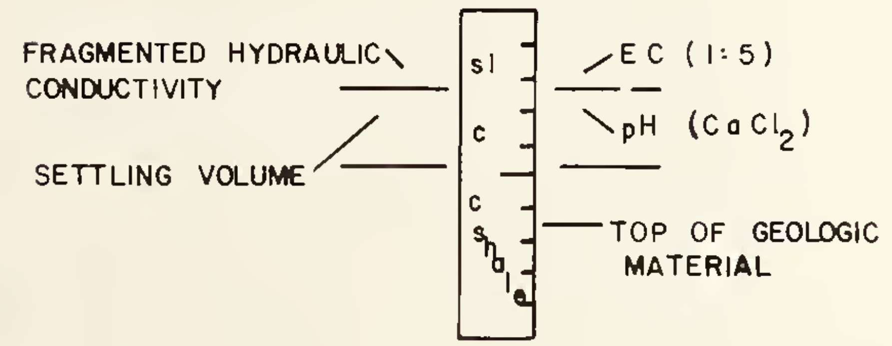




SCALE: 1" = 1000'

TWP. 19N SEC. 18 RANGE 90W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME
8060	HAVRE SANDY LOAM A - 0 to 3 PERCENT B - 3 to 7 PERCENT
8070	ROCK RIVER SANDY LOAM B - 3 to 7 PERCENT C - 7 to 12 PERCENT
8080	CUSHOOL SANDY LOAM B - 3 to 7 PERCENT C - 7 to 12 PERCENT
8100	HAVRE SANDY LOAM ALKALINE A - 0 to 3 PERCENT
8110	WORFMAN SANDY LOAM, DELPHILL FINE SANDY LOAM BD - 3 to 20 PERCENT C - 7 to 12 PERCENT
8120	SPOOL AND COTHRAN LOAMY SAND CE - 7 to 40 PERCENT OE - 12 to 40 PERCENT
8130	ROCK RIVER - PATENT FINE SANDY LOAM COMPLEX BD - 3 to 20 PERCENT CO - 7 to 20 PERCENT
8140	ROCK RIVER - RYARK SAND LOAM COMPLEX B - 3 to 7 PERCENT BC - 3 to 12 PERCENT C - 7 to 12 PERCENT
8150	SKOOTCH SANDY LOAM, BLAYON LOAM CD - 7 to 20 PERCENT OE - 12 to 40 PERCENT
8160	ROCKLAND OE - 12 to 40 PERCENT

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

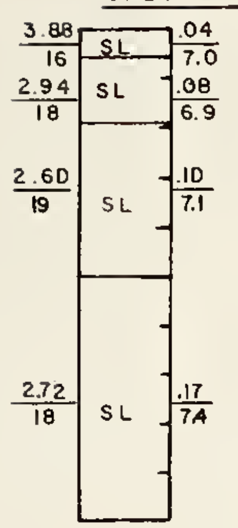
SOIL INVENTORY

RED RIM STUDY AREA - WYOMING

DESIGNED W.C. LAUBNER SUBMITTED
DRAWN L. SHANKLIN RECOMMENDED
CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO. | FIGURE C-6

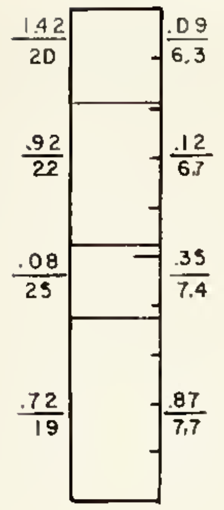
NO. 8-1



LOCATION: 300' NORTH 350' SOUTH OF SE CORNER OF SE$\frac{1}{4}$ NE$\frac{1}{4}$

PM: AEOLIAN DEPOSITION

NO. DH-7

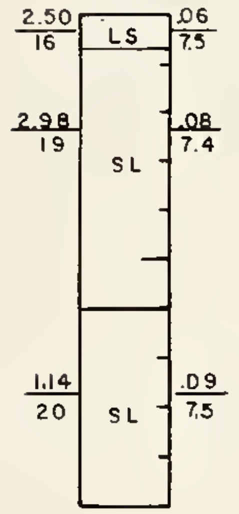


LOCATION: 200' NORTH 250' WEST OF SE CORNER OF SE$\frac{1}{4}$ NW$\frac{1}{4}$

NO.

NO.

NO. 8-2



LOCATION: 400' SOUTH 200' EAST OF NW CORNER OF NE$\frac{1}{4}$ SE$\frac{1}{4}$

PM: ALLUVIUM

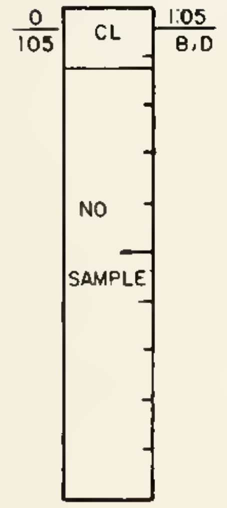
REMARKS: COARSER TEXTURED THAN MOST OF SURROUNDING AREA

NO.

NO.

NO.

NO. 8-3



LOCATION: 500' SOUTH 450' EAST OF NW CORNER OF SE$\frac{1}{4}$ SE$\frac{1}{4}$

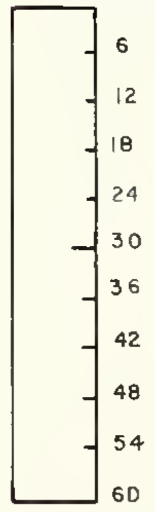
PM: ALLUVIUM

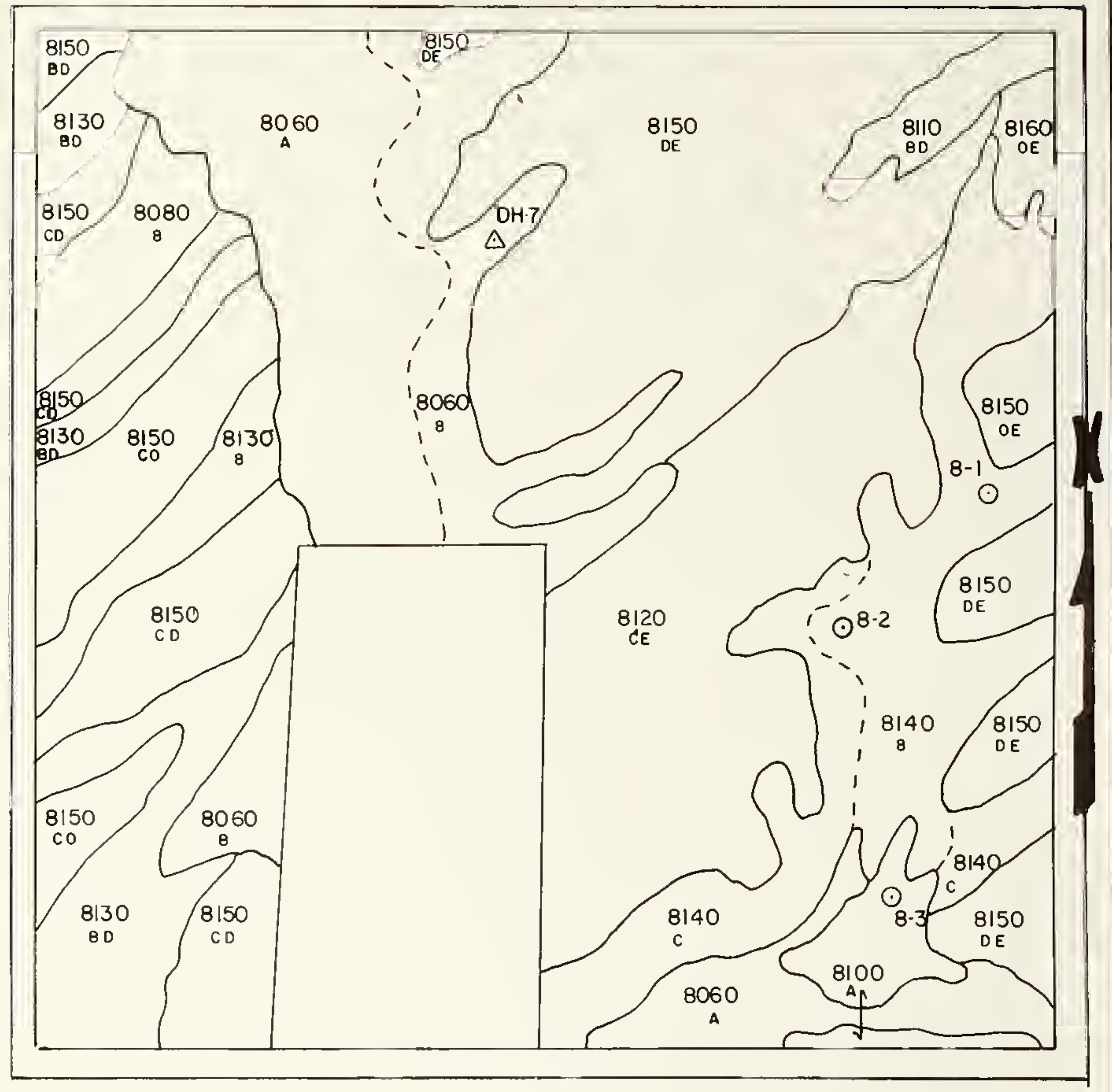
REMARKS: VISUAL OBSERVATION OF EXISTING VEGETATION AND SOIL CONDITION PRECLUDE FURTHER SAMPLING

NO.

NO.

NO. DEPTH IN INCHES

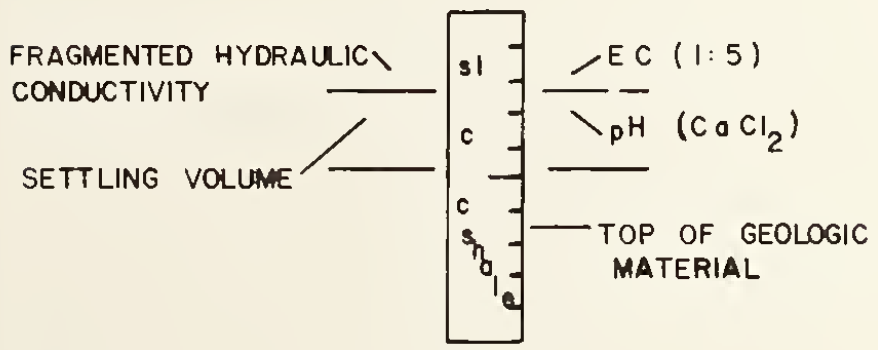




SCALE: 1" = 1000'

TWP. 19N SEC. 8 RANGE 90W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME	NUMBER	NAME
8060	HAVRE SANDY LOAM A- 0 to 3 PERCENT B - 3 to 7 PERCENT	8120	SPOOL AND COTHRAN LOAMY SAND CE-7 to 40 PERCENT DE-12 to 40 PERCENT
8070	ROCK RIVER SANDY LOAM B - 3 to 7 PERCENT C - 7 to 12 PERCENT	8130	ROCK RIVER – PATENT FINE SANDY LOAM COMPLEX 80 - 3 to 20 PERCENT CD - 7 to 20 PERCENT
8080	CUSHOOL SANDY LOAM B- 3 to 7 PERCENT C-7 to 12 PERCENT	8140	ROCK RIVER– RYARK SAND LOAM COMPLEX B - 3 to 7 PERCENT BC- 3 to 12 PERCENT C - 7 to 12 PERCENT
8100	HAVRE SANDY LOAM ALKALINE A - 0 to 3 PERCENT	8150	SKOOTCH SANDY LOAM, BLAYON LOAM CO - 7 to 20 PERCENT DE - 12 to 40 PERCENT
8110	WORFMAN SANDY LOAM, DELPHILL FINE SANDY LOAM 80 - 3 to 20 PERCENT C - 7 to 12 PERCENT	8160	ROCKLAND OE - 12 to 40 PERCENT

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

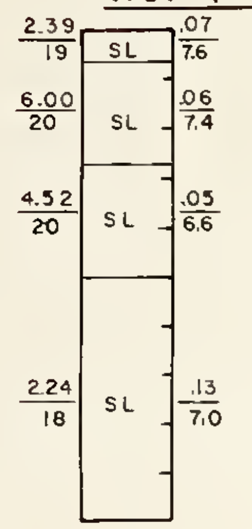
SOIL INVENTORY

RED RIM STUDY AREA – WYOMING

DESIGNED W.C. LAUBNER SUBMITTED
DRAWN L. SHANKLIN RECOMMENDED
CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO. | FIGURE C-7

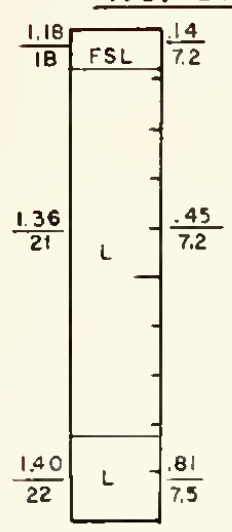
NO. 4-1



LOCATION: 150' NORTH 550' WEST OF SE CORNER OF NE $\frac{1}{4}$ SE $\frac{1}{4}$

PM: VALLEY FILL (ALLUVIUM)

NO. DH-6



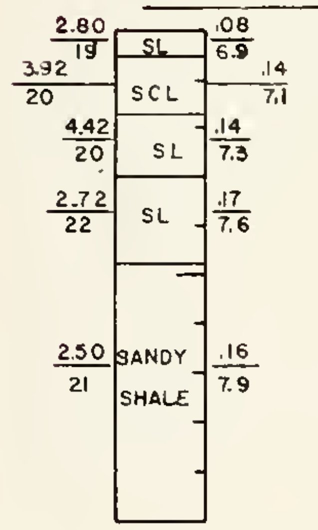
LOCATION: 400' SOUTH 300' EAST OF NW CORNER OF SW $\frac{1}{4}$ SW $\frac{1}{4}$

PM: ALLUVIUM

NO.

NO.

NO. 4-2



LOCATION: 350' SOUTH 150' EAST OF NW CORNER OF NE $\frac{1}{4}$ NE $\frac{1}{4}$

PM: SANDY SHALE

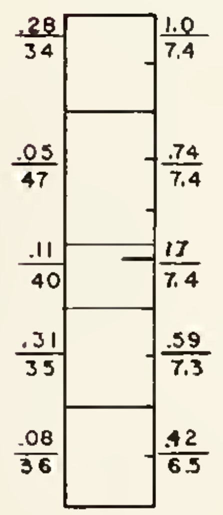
REMARKS: BIRDS FOOT SAGE, STRONG MEDIUM COLUMNAR STRUCTURE

NO.

NO.

NO.

NO. DH-5



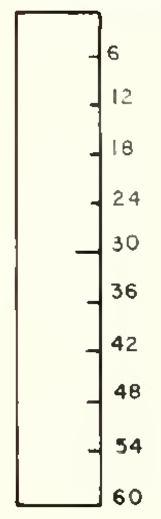
LOCATION: 150' SOUTH 150' WEST OF NE CORNER OF SE $\frac{1}{4}$ NW $\frac{1}{4}$

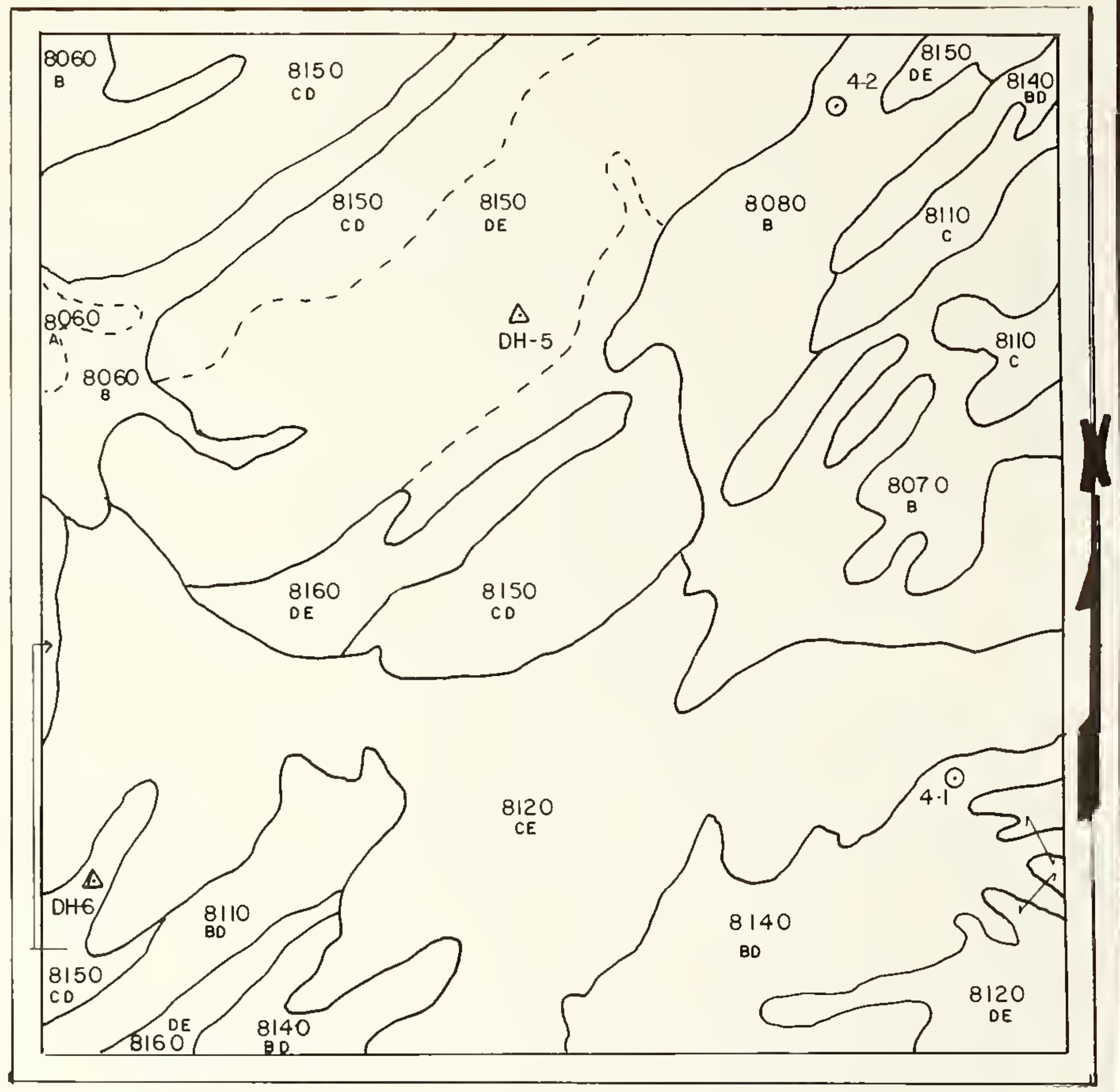
PM: SANDSTONE

NO.

NO.

NO. DEPTH IN INCHES

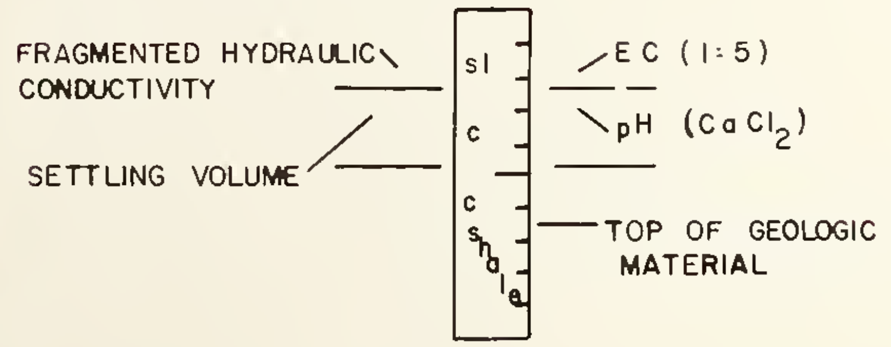




SCALE: 1" = 1000'

TWP. 19N SEC. 4 RANGE 90W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME
8060	HAVRE SANDY LOAM A- 0to3 PERCENT B- 3to7 PERCENT
8070	ROCK RIVER SANDY LOAM B- 3to7 PERCENT C- 7to12 PERCENT
8080	CUSHOOL SANDY LOAM B- 3to7 PERCENT C- 7to12 PERCENT
8100	HAVRE SANDY LOAM ALKALINE A- 0to3 PERCENT
8110	WORFMAN SANDY LOAM, DELPHILL FINE SANDY LOAM BD- 3to20 PERCENT C- 7to12 PERCENT
8120	SPOOL AND COTHRAN LOAMY SAND CE- 7to40 PERCENT DE- 12to40 PERCENT
8130	ROCK RIVER – PATENT FINE SANDY LOAM COMPLEX BD- 3to20 PERCENT CD- 7to20 PERCENT
8140	ROCK RIVER – RYARK SAND LOAM COMPLEX B- 3to7 PERCENT BC- 3to12 PERCENT C- 7to12 PERCENT
8150	SKOOTCH SANDY LOAM, BLAYON LOAM CD- 7to20 PERCENT DE- 12to40 PERCENT
8160	ROCKLAND DE- 12to40 PERCENT

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

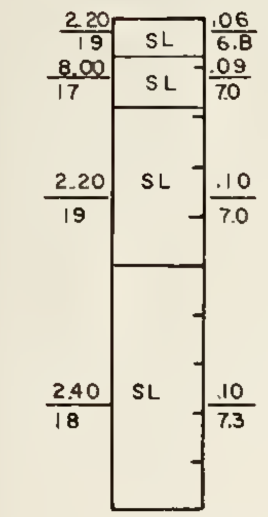
SOIL INVENTORY

RED RIM STUDY AREA – WYOMING

DESIGNED W.C. LAUBNER SUBMITTED
DRAWN L. SHANKLIN RECOMMENDED
CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO | FIGURE C-8

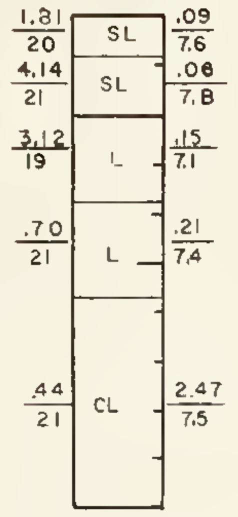
NO. 34-1



LOCATION: 500' NORTH 150' WEST OF SE CORNER OF NW $\frac{1}{4}$ SE $\frac{1}{4}$

PM: VALLEY FILL (ALLUVIUM)

NO. DH-2



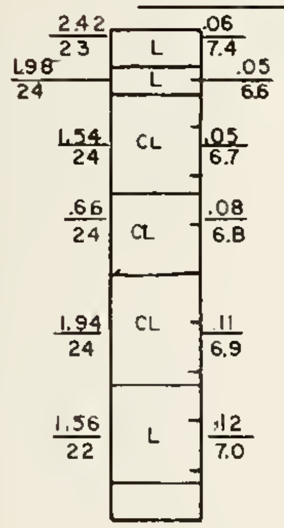
LOCATION: 250' SOUTH 500' EAST OF NW CORNER OF NW $\frac{1}{4}$ NW $\frac{1}{4}$

PM: HARD CALCAREOUS SAND

NO.

NO.

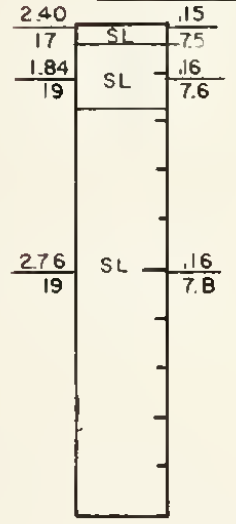
NO. 34-2



LOCATION: 200' NORTH 400' WEST OF SE CORNER OF NE $\frac{1}{4}$ SW $\frac{1}{4}$

PM: VALLEY FILL (ALLUVIUM)

NO. DH-3



LOCATION: 150' SOUTH 200' WEST OF NE CORNER OF NE $\frac{1}{4}$ SW $\frac{1}{4}$

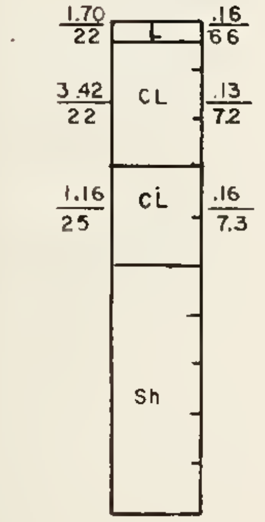
PM: VALLEY FILL (ALLUVIUM)

REMARKS: NEEDLELEAF SEDGE, NEEDLE AND THREAD, INDIAN RICEGRASS.

NO.

NO.

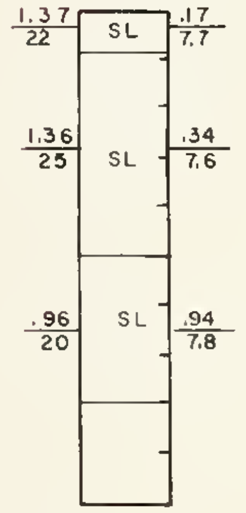
NO. 34-3



LOCATION: 600' SOUTH 450' EAST OF NW CORNER OF SW $\frac{1}{4}$ SW $\frac{1}{4}$

PM: SHALE

NO. DH-4

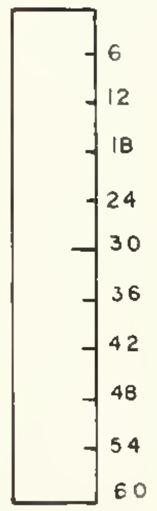


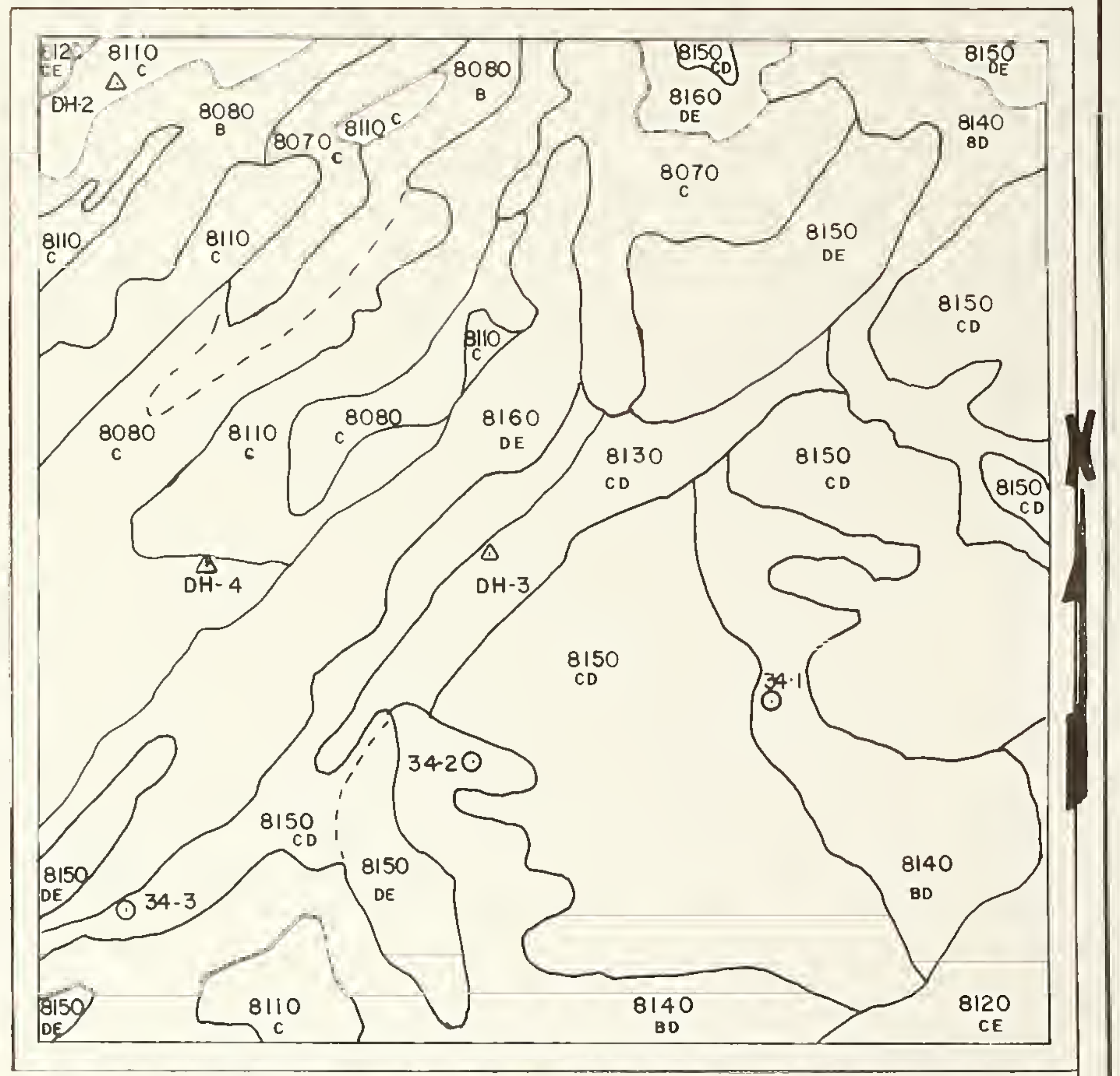
LOCATION: 100' SOUTH 500' EAST OF NE CORNER OF NW $\frac{1}{4}$ SW $\frac{1}{4}$

PM: SOFT CALCAREOUS SANDSTONE

NO.

NO. DEPTH IN INCHES

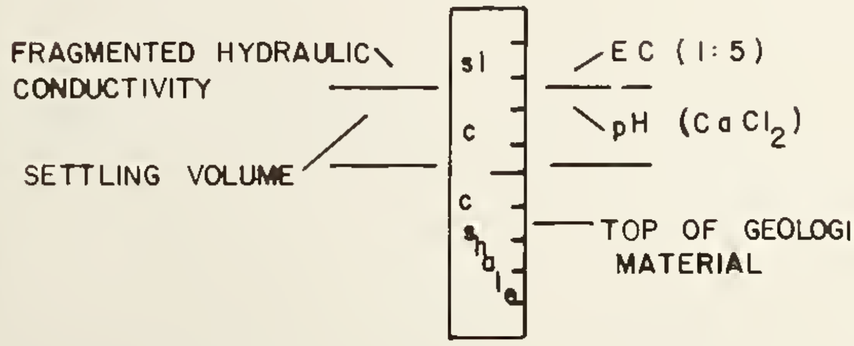




SCALE: 1" = 1000'

TWP. 20N SEC. 34 RANGE 90W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME
8060	HAVRE SANDY LOAM A - 0 to 3 PERCENT B - 3 to 7 PERCENT
8070	ROCK RIVER SANDY LOAM B - 3 to 7 PERCENT C - 7 to 12 PERCENT
8080	CUSHOOL SANDY LOAM B - 3 to 7 PERCENT C - 7 to 12 PERCENT
8100	HAVRE SANDY LOAM ALKALINE A - 0 to 3 PERCENT
8110	WORFMAN SANDY LOAM, DELPHILL FINE SANDY LOAM BD - 3 to 20 PERCENT C - 7 to 12 PERCENT
8120	SPOOL AND COTHRAN LOAMY SAND CE - 7 to 40 PERCENT DE - 12 to 40 PERCENT
8130	ROCK RIVER - PATENT FINE SANDY LOAM COMPLEX BD - 3 to 20 PERCENT CD - 7 to 20 PERCENT
8140	ROCK RIVER - RYARK SANDY LOAM COMPLEX B - 3 to 7 PERCENT BC - 3 to 12 PERCENT C - 7 to 12 PERCENT
8150	SKOOTCH SANDY LOAM, BLAYON LOAM CD - 7 to 20 PERCENT DE - 12 to 40 PERCENT
8160	ROCKLAND DE - 12 to 40 PERCENT

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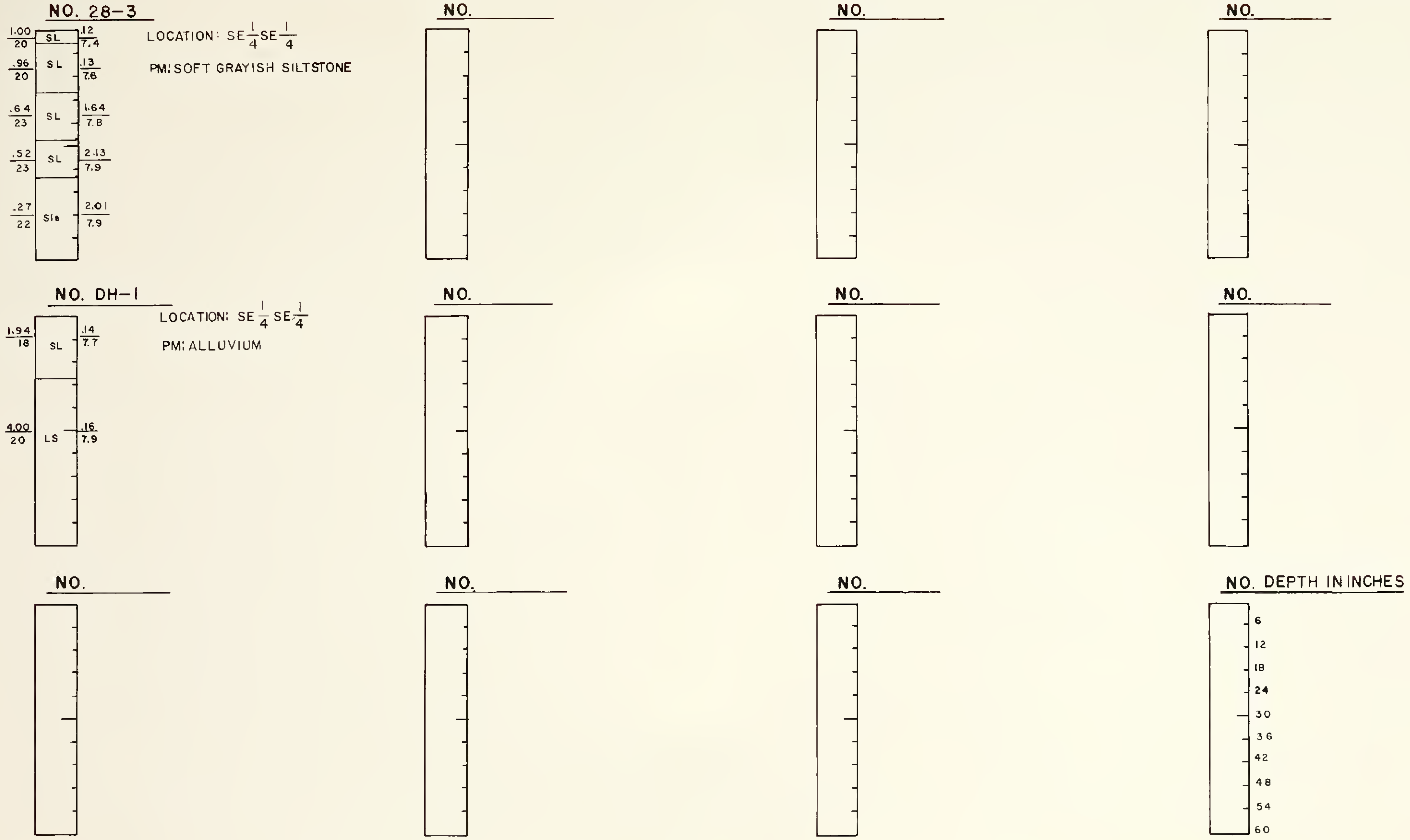
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

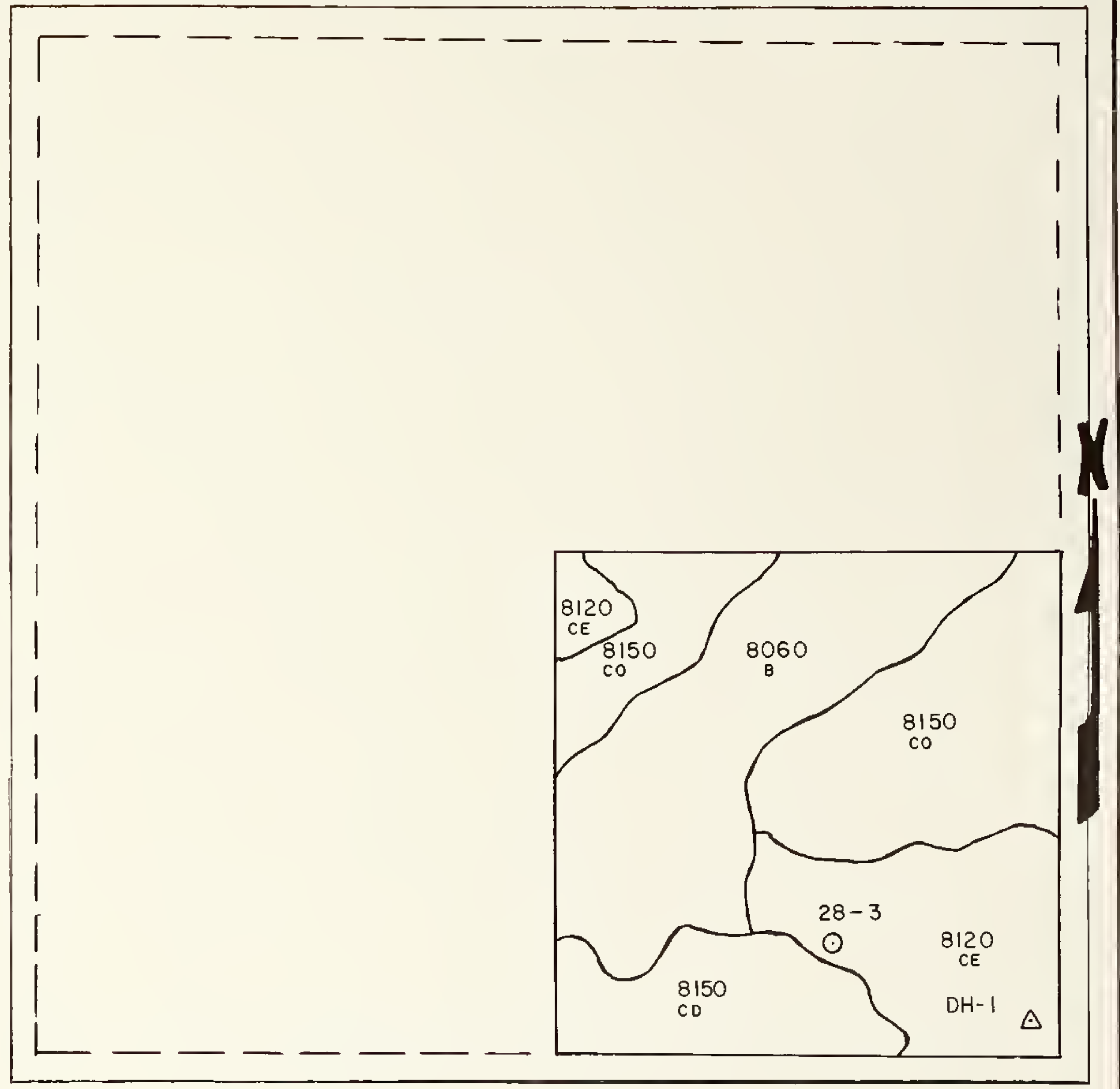
SOIL INVENTORY

RED RIM STUDY AREA — WYOMING

DESIGNED W.C. LAUBNER ___ SUBMITTED ___
DRAWN L. SHANKLIN ___ RECOMMENDED ___
CHECKED T. CAPPELLUCCI ___ APPROVED ___

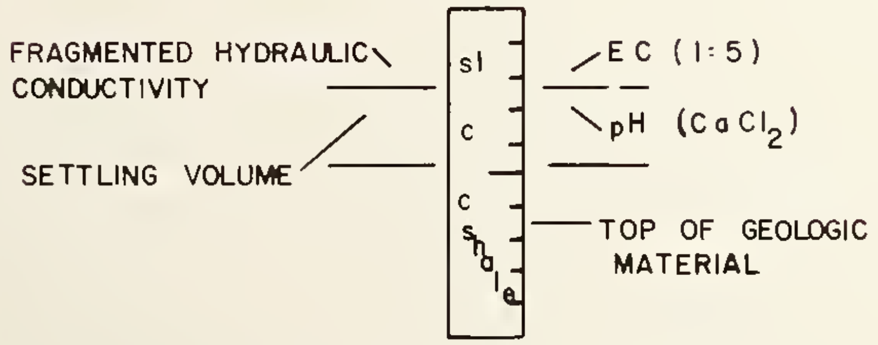
LM REGION, DEN., COLO. | FIGURE C-9





SCALE: 1" = 1000'

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

SOIL MAPPING UNIT

NUMBER	NAME
8060	HAVRE SANDY LOAM A-0 to 3 PERCENT B-3 to 7 PERCENT
8070	ROCK RIVER SANDY LOAM B-3 to 7 PERCENT C-7 to 12 PERCENT
8080	CUSHOOL SANDY LOAM B-3 to 7 PERCENT C-7 to 12 PERCENT
8100	HAVRE SANDY LOAM ALKALINE A-0 to 3 PERCENT
8110	WORFMAN SANDY LOAM, DELPHILL FINE SANDY LOAM BD-3 to 20 PERCENT C-7 to 12 PERCENT
8120	SPOOL AND COTHRAN LOAMY SAND CE-7 to 40 PERCENT OE-12 to 40 PERCENT
8130	ROCK RIVER-PATENT FINE SANDY LOAM COMPLEX BD-3 to 20 PERCENT CD-7 to 20 PERCENT
8140	ROCK RIVER-RYARK SAND LOAM COMPLEX B-3 to 7 PERCENT BC-3 to 12 PERCENT C-7 to 12 PERCENT
8150	SKOOTCH SANDY LOAM, BLAYON LOAM CO-7 to 20 PERCENT OE-12 to 40 PERCENT
8160	ROCKLAND OE-12 to 40 PERCENT

TWP. 20N SEC. 28 RANGE 90 W

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SOIL INVENTORY

RED RIM STUDY AREA – WYOMING

DESIGNED W.C. LAUBNER SUBMITTED
DRAWN L. SHANKLIN RECOMMENDED
CHECKED T. CAPPELLUCCI APPROVED

LM REGION, DEN., COLO. | FIGURE C-10

HAVRE SERIES

A_1	0-2" -	Brown (10YR 5/3) sandy clay loam; dark brown (10YR 4/3) moist; medium, moderate crumb; slightly hard, very friable; strongly calcareous, moderately alkaline, pH 8.4; clear, smooth boundary.
C_1	2-28" -	Pale brown (10YR 6/3) sandy clay loam; dark brown (10YR 4/3) moist; stratified with lenses of loam, silt loam and very fine sandy loam; massive; slightly hard, very friable; violent effervenscence, moderately alkaline, pH 8.4; clear smooth boundary.
C_2	28-38" -	Pale brown (10YR 6/3) sandy clay loam; dark brown (10YR 4/3) moist; strata of sandy loam, loamy sand evident; massive; soft, very friable; strongly calcareous; strongly alkaline, pH 8.6; gradual, smooth boundary.
C_3	38-60" -	Pale brown (10YR 6/3) fine sandy loam; dark brown (10YR 4/3) moist; strata of loam, loamy fine sand; massive; soft, very friable; strongly calcareous; strongly alkaline, pH 8.6.

U S DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Havre Series

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
Wy	Rawlins	- -	G. saltbrush, Big sage / Greasewood	8060	- - - -	8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
Red Rim	Carbon	Sec. 8, T. 19N, R. 90W	016	- - - -	- - - -	Local Alluvium

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Ft. Union	Stone 0 Rock 0	Alkaline Slight Saline Mod. Water table ∠6'	Alluvial fan.

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
3% X Single __ Complex	NE	6870	Type SSF 43 Class Moderate	B -

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14" - 1st, 2nd, 3rd, 4th	∠47° Air - - Soil	Days - - - > 28°	Somewhat Poorly Drained	Moderate		- - in	- - . - in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-2	10 YR 5/3 10 YR 4/3		Lt. SCL	m2cr	dsh mvfri		/1		es 8.4	cs
C_1ca	2-28	10 YR 6/3 10 YR 4/3		SCL	m	dsh mvfri				ev 8.4	cs
C2	28-38	10YR 6/3 10YR 4/3		Lt. SCL	m	ds mvfri				es 8.6	gs
C3	38-60	10YR 6/3 10YR 4/3		FSL	m	ds mvfri				es 8.6	

/1 Many F,M & few C-0-10
Few M&C 10-16"
Few C 16-24"

ROCK RIVER SERIES

A_1	0-4" -	Grayish brown (10YR 5/2) sandy loam; very dark grayish brown (10YR 3/2) moist; medium moderate crumb; hard, very friable, noncalcareous; neutral; clear, smooth boundary.
B_21t	4-7" -	Yellowish brown (10YR 5/4) sandy clay loam; dark grayish brown (10YR 4/2) moist; medium weak subangular blocky; very hard, firm, few patchy clay films on vertical ped faces; noncalcareous; mildly alkaline; clear, smooth boundary.
B_22t	7-20" -	Yellowish brown (10YR 5/4) sandy clay loam; dark brown (10YR 4/3) moist; medium, strong angular blocky breaking to fine strong angular blocky; very hard, firm; thick continuous clay films on both vertical and horizontal ped faces; noncalcareous; mildly alkaline; clear, smooth boundary.
B_23	20-30" -	Yellowish brown (10YR 5/4) sandy clay loam; dark brown (10YR 4/3) moist; medium, moderate angular blocky breaking to fine moderate subangular blocky; slightly hard, friable; thin continuous clay coats on vertical faces, thin patchy on horizontal ped faces; noncalcareous; moderately alkaline; clear, smooth boundary.
B_3ca	30-40" -	Light olive brown (2.5Y 5/4) clay loam; olive brown (2.5Y 4/4) moist; medium, moderate angular blocky; slightly hard, firm; thin, patchy clay films; calcareous; moderately alkaline; gradual, smooth boundary.
C	44-56" -	Light olive brown (2.5Y 5/4) clay loam; olive brown (2.5Y 4/4) moist; massive, slightly hard, firm; strongly calcareous; moderately alkaline, gradual smooth boundary.
Cr	56"+ -	Nonconsolidated light yellowish brown calcareous sandstone.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Rock River Series

VEGETATION-SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation-Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
WY	Rawlins		B.sage, Needle & thread, thick spike wheatgrass	8070		8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
Red Rim	Sweetwater	Rabbit brush SE Sec. 34, T. 20N, R. 90W				

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone 0 Rock 0	Alkaline None Saline None Water table > 6'	Valley fill side slope

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
7-12% Single X Complex	E-NE	7100	Type SSF 37 Class Slight	B

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14" 1st, 2nd, 3rd, 4th	Less than 47°F Air Soil	Days > 28°	Well	Moderate		in	in

32. HORIZON	33. THICKNESS	34. COLOR (DRY / MOIST) MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-4	10YR 5/2 3/2		SL	M2cr	Dh Mvfr		/3	0	eo	cs
B_{21t}	4-7	10YR 5/4 4/2		SCL	M1sbk	Dvh Mfi	few patchy		0	eo	cs
B_{22t}	7-20	10YR 5/4 4/3		SCL	m3abk-f3abk	Dvh Mfi	/1		0	eo	cs
B_{23}	20-30	10YR 5/4 4/3		SCL	m2abk-f2sbk	Dsh Mfr	/2		0	eo	cs
B_{3ca}	30-44	2.5Y 5/4 4/4		CL	m2abk	Dsh Mfi	Thin discontinuous		0	e	gs
C_{ca}	44-56	2.5Y 5/4 4/4		CL	m	Dsh Mfi				es	gs
Cr	56+	Unconsolidated lt. yellowish brown calcareous sandstone									

/1 Thick continuous clay film on both vertical & horizontal ped faces

/2 Thin continuous on vertical, thin patchy on horizontal

/3 Many F & M - 3", May F-M-C-9", Few M& C-18", Few C-26"

/3 Many fine & medium 0-3", many fine, medium & coarse, 3-9", few medium & coarse 9-18", few coarse 18-26"

CUSHOOL SERIES

A_1	0-3"	-	Brown (10YR 5/3) sandy loam; dark yellowish brown (10 YR 4/4) moist; thick crust breaking to fine, weak crumb; slightly hard, friable; noncalcareous, neutral, pH 7.2; clear, smooth boundary.
B_21t	3-11"	-	Yellowish brown (10YR 5/4) sandy clay loam, 30 percent clay, dark yellowish brown (10YR 4/4) moist; medium, moderate prismatic breaking to medium, moderate angular blocky; hard, firm; thin nearly continuous films and patches of thick coatings on vertical and horizontal ped faces; noncalcareous; mildly alkaline, pH 7.6; clear, smooth boundary.
B_22t	11-18"	-	Yellowish brown (10YR 5/4) sandy clay loam, 24 percent clay; dark yellowish brown (10YR 4/4) moist; coarse, weak prismatic breaking to medium, moderate angular blocky; slightly hard, firm; thin discontinuous waxy coatings and sand bridges; noncalcareous; mildly alkaline, pH 7.6; gradual wavy boundary.
B_3ca	18-24"	-	Slight yellowish brown (10YR 6/4) sandy loam; yellowish brown (10YR 5/4) moist; medium, weak angular blocky; slightly hard, friable; few, thin patchy clay films and sand bridges; violent effervescense, many medium and coarse specks and seams of calcium carbonate moderately alkaline, pH 8.5; gradual, wavy boundary.
Cca	24-30"	-	Light yellowish brown (10YR 6/4) sandy loam; yellowish brown (10YR 5/4) moist; structureless; slightly hard, very friable; violent effervescence, many fine and medium spots and threads of calcium carbonate; strongly alkaline, pH 8.6; gradual, wavy boundary.
Cr	30"+	-	Soft calcareous yellowish brown sandstone interbedded with light gray sandy shale.

U.S. DEPARTMENT OF THE INTERIOR
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Cushool Series

VEGETATION–SOIL DESCRIPTION

1. State WY	2. District Rawlins	3. Planning Unit --	4. Vegetation–Soil Unit Needle & thread, Big sage, Prairie Junegrass / thick spike wheatgrass	5. Soil Map Symbol 8080	6. Surname --	7. Date 8 mo 75 yr
8. Area --	9. County Sweetwater	10. Location Sec. 34, T 20N, R. 90W	11. Photo No. --	12. Writeup No. --	13. File No. --	14. Parent Rock Sandy shale

15. Formation Name: Fort Union	16. Surface Conditions (percent): Stone -- Rock --	17. Land Conditions: Alkaline - Saline - Water table >6'	18. Landform: Side slope
19. Slope (percent) 3-7%; X Single ☐ Complex	20. Aspect E-NE; 21. Elevation 7100	22. Present Erosion: Type; SSF 36 Class -	23. Hydrologic Group B -

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14" - (1st, 2nd, 3rd, 4th)	Less than 47°F Air -- Soil	Days -- > 28°	Well	Moderate		-- in	--.-- in

32. HORIZON	33. THICKNESS	34. COLOR (DRY/MOIST) MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-3	10YR 5/3 4/4		sl	Thick crust f1cr	sh fr		*5		7.2 eo	cs
B21t	3-11	10YR 5/4 4/4		30% scl	m2pr m2abk	h fi	*1			7.6 eo	cs
B22t	11-18	10YR 5/4 4/4		24% scl	c1pr m1abk	sh fi	*2			7.6 eo	gw
B3ca	18-24	10YR 6/4 5/4		sl	m1abk	sh fr	*3			8.5 ev	gw
Cca	24-30	10YR 6/4 5/4		sl	0	sh	*4			8.6 ev	gw
Cr	30+	Soft calc. yellowish brown sandstone interbedded with sandy shale									

*1 Thin nearly continuous films and patches of thick coatings on vertical & horizontal ped faces.

*2 Thin discontinuous waxy coatings sand bridges

*3 Many medium and coarse spots and seams of $CaCO_3$, and few thin patchy clay films and sandy bridges

*4 Many fine & medium spots & threads of $CaCo_3$

*5 Many fine & medium to 3", common fine and medium to 11, few medium & coarse 11-18, few coarse 18-24"

WORFMAN SERIES

A_1	0-3"	-	Brown (10YR 5/3) sandy loam; dark (10YR 4/3) moist; fine moderate crumb; soft, very friable; noncalcareous, neutral, pH 7.2; clear, smooth boundary.
B_2t	3-10"	-	Brown (10YR 5/3) sandy clay loam, 24 percent clay; dark brown (10YR 4/3) moist; medium, weak prismatic breaking to medium, moderate angular blocky; slightly hard, friable; thin, discontinuous waxy clay coatings on vertical and horizontal ped faces; noncalcareous; mildly alkaline, pH 7.6; clear, smooth boundary.
B_3ca	10-17"	-	Light brownish gray (10YR 6/2) sandy clay loam, 22 percent clay, dark brown (10YR 4/3) moist; fine and medium weak angular blocky; slightly hard, friable; few, thin, patchy waxy coatings; violent effervescence, many fine and medium spots and seams of calcium carbonate; strongly alkaline, pH 8.5; gradual, waxy boundary.
Cr	17"+	-	Soft calcareous sandy shale; pale brown.

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Worfman Series

VEGETATION-SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation-Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
WY	Rawlins	--	*1	8110		8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
Red Rim	Sweetwater	Sec. 34, T. 20N, R. 90W				Soft Calc. S.S.

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Ft. Union	Stone -- Rock --	Alkaline - Saline - Water table >6'	Sideslope

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
6% Single __ Complex X	North	7100	Type SSF 41 Class Moderate	B

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14" - 1st, 2nd, 3rd, 4th	Less than 47°F Air -- Soil	Days --> 28°	Well	Moderate		-- in	--.-- in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY	MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-3	10YR 5/3 4/3		SL	f2cr	s	vfr		*4		7.2 eo	cs
B2t	3-10	10YR 5/3 4/3		SCL 24%	m1pr - m2abk	sh	fr	*2			7.6 eo	cs
B_3ca	10-17	10YR 6/2 4/3		SCL 22%	f&m1abk	sh	fr	*3			8.5 ev	gw
Cr	17+	Soft calcareous sandy shale, pale brown									ev	

*1 Rabbitbrush, Big sage, Needle & thread, Prairie Junegrass, needle-leaf sedge

*2 Thin, discontinuous waxy

*3 Many fine and medium spots & seams of $CaCO_3$ & few thin patchy waxy

*4 Many fine & medium 0-3", common medium & coarse 3-10", few coarse to 10-17"

DELPHILL SERIES

A_1	0-3" -	Brown (10YR 5/3) fine sandy loam; dark brown (10YR 4/3) moist; fine moderate crumb; soft, very friable; strongly calcareous, clear, smooth boundary.
C_1	3-16" -	Pale brown (10YR 6/3) very fine sandy loam; yellowish brown (10YR 5/4) moist; massive; slightly hard, very friable; strongly calcareous; clear, smooth boundary.
C_2	16-28" -	Pale brown (10YR 6/3) very fine sandy loam; brown (10YR 5/3) moist; massive; slightly hard, very friable; calcareous; clear, smooth boundary.
Cr	28"+ -	Soft grayish brown siltstone.

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Delphill Series

VEGETATION-SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
Wyo	Rawlins	--	*1	8110		10 mo 75

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
Red Rim	Sweetwater	Sec. 28, T. 20N, R. 90W				Gray Siltstone

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Ft. Union	Stone -- Rock 5%	Alkaline - Saline - Water table >6'	Sidehill

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
10% ☐ Single ☒ Complex	W	6860	Type SSF 41 Class Moderate	B

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14 - 1st, 2nd, 3rd, 4th	Less than 47°F Air -- Soil	Days -->28°	Well	Moderate		-- in	--.-- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-3	10YR 5/3 4/3		fsl	f2cr	s vfr	0			es	cs
C_1	3-16	10YR 6/3 5/4		vfsl	m	sh vfr	0			es	cs
C2	16-28	10YR 6/3 5/3		vfsl	m	sh vfr	0			e	cs
Cr	28" soft grayish brown siltstone					h vfr	0			e	cs

*1 Big sage, thick spike wheatgrass, phlox, needle-leaf sedge

*2 Many fine and medium 0-3, common fine and medium 3-16", few coarse 16-28"

SPOOL SERIES

A_1	0-1"	-	Pale brown (10YR 6/3) loamy sand; dark brown (10YR 4/3) moist; hard crust; massive; slightly hard, loose; noncalcareous, neutral, pH 7.2; clear, smooth boundary.
C_1	1-3"	-	Pale brown (10YR 6/3) loamy sand; dark brown (10YR 4/3) moist; single grain; loose both dry and moist; noncalcareous; neutral; pH 7.2; clear, smooth boundary.
C_2	3-8"	-	Yellowish brown (10YR 5/4) fine sand; dark yellowish brown (10YR 4/4) moist; single grain; loose both dry and moist; noncalcareous; neutral pH 7.2; clear, smooth boundary.
R	8"+	-	Hard, noncalcareous sandstone.

Spool Series

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
WY	Rawlins	--	*1 / -	8120	-	10 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
Red Rim	Carbon	Sec. 4, T. 19N, R. 90W	-	-	-	Hard noncalc. S.S.

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone -- Rock None	Alkaline - Saline - Water table > 6'	Sidehill slope

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
--- ☐ Single ☒ Complex	NE	7120	Type SSF 38 Class Slight	A -

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14 - (1st, 2nd, 3rd, 4th)	Less than 47°F Air -- Soil	Days --- > 28°	Excessive	Rapid	Rapid	-- in	--.- in

32. HORIZON	33. THICKNESS	34. COLOR Dry — MATRIX	34. COLOR ~~Dry~~ ~~Moist~~ Moist — MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY	37. CONSISTENCY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-1	10YR 6/3	10YR 4/3	LS	Hard Crust	sh	1	0			7.2 eo	cs
C_1	1-3	10YR 6/3	10YR 4/3	LS	sg	1	1	0	*1	0	7.2 eo	cs
C_2	3-8	10YR 5/4	10YR 4/4	FS	sg	1	1	0		0	7.2 eo	cs
R	8+	Hard, noncalcareous sandstone.										

*1 Rabbitbrush, Prairie junegrass, Phlox

*2 Many fine & medium 0-3", few medium 3-8"

COTHRAN SERIES

A_1	0-2"	-	Pale brown (10YR 6/3) fine sand; dark brown (10YR 4/3) moist; single grain; loose both dry and moist; noncalcareous; neutral, pH 7.2; clear smooth boundary.
C_1	2-30"	-	Yellowish brown (10YR 5/4) fine sand; dark yellowish brown (10YR 4/4) moist; single grain; loose both dry and moist; noncalcareous; mildly alkaline pH 7.4; clear, smooth boundary.
C_2	30-60"	-	Brown (10YR 5/3) loamy sand, dark brown (10YR 4/3) moist; massive breaking easily to single grain; loose both dry and moist; noncalcareous; mildly alkaline, pH 7.4.

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Cothran Series

VEGETATION-SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
WY	Rawlins		*1 /	8120		10 mo 75 yr

8. Area	9. County	10. Location	11. Photo No	12. Writeup No.	13. File No	14. Parent Rock
Red Rim	Sweetwater	Sec 5 T [illegible] R [illegible]				Aeolian sand

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
	Stone 0 Rock 0	Alkaline – Saline – Water table > 6'	Sand dune

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
8% ☐ Single [X] Complex	W	7080	Type SSF 38 Class Slight	A

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14" – 1st, 2nd, 3rd, 4th	Less than 47°F Air – – Soil	Days – – – > 28°	Excessive	Rapid	Very Rapid	– – in	– – . – in

32. HORIZON	33. THICKNESS	34. COLOR DRY	34. COLOR MOIST	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY	37. CONSISTENCY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-2	10YR 6/3	10YR 4/3	fs	sg	1	1		*2		7.2 eo	cs
C_1	2-30	10YR 5/4	10YR 4/4	ls	sg	1	1			*3	7.4 eo	cs
C_2	30-60	10YR 5/3	10YR 4/3	ls	m-sg	1	1				7.4 eo	

*1 Rabbitbrush, Mahogony, Prairie Junegrass, Sandberg bluegrass, Indian Rice grass

*2 Many fine and medium 0-2", many fine and medium 2-10", few coarse 10-18"

*3 Many fine gravels & ironstones ¼-1" in diameter

PATENT SERIES

A_1	0-2"	-	Pale brown (10YR 6/3) loam; dark brown (10YR 4/3) moist; medium and coarse, moderate crumb; slightly hard, friable; calcareous, moderately alkaline, pH 8.4; clear, smooth boundary.
C_1ca	2-21"	-	Brown (10YR 5/3) loam; dark brown (10YR 4/3) moist; coarse weak subangular blocky; slightly hard, friable; calcareous, few, fine distinct lime concretions moderately alkaline, pH 8.4; clear, smooth boundary.
C_2ca	21-60"	-	Brown (10YR 5/3) loam; dark brown (10YR 4/3) moist; structureless; slightly hard, friable; violent effervescence, many fine and medium lime specks and threads; strongly alkaline, pH 8.7.

U.S. DEPARTMENT OF THE INTERIOR
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Patent Series

VEGETATION-SOIL DESCRIPTION

1. State WY	2. District Rawlins	3. Planning Unit	4. Vegetation-Soil Unit Big sage, thick-spike wheatgrass	5. Soil Map Symbol 812C	6. Surname	7. Date 10 mo 75 yr
8. Area Red Rim	9. County Carbon	10. Location Sec. 18, T. 19N, R. 90W	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock Alluvium-slope wash
15. Formation Name Ft. Union	16. Surface Conditions (percent) Stone – – Rock – –	17. Land Conditions Alkaline – Saline – Water table > 6'				18. Landform Alluvial fan
19. Slope (percent) 6% X Single Complex	20. Aspect West	21. Elevation 7150	22. Present Erosion Type SSF 35 Class Slight			23. Hydrologic Group B –
24. Precipitation (in) 10-14" – 1st, 2nd, 3rd, 4th	25. Temperature Less than 47°F Air – – Soil	26. Frost-free Days – – –> 28°	27. Drainage Class Well	28. Infiltration Moderate	29. Percolation Moderate	30. ERD – – in; 31. AWC – – . – in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-2	10YR 6/3 4/3		1	m&c2cr	sh fr	0	*3		8.4 e	cs
C_1ca	2-21	10YR 5/3 4/3	*1	1	c1sabk	sh fr				8.4 e	cs
C_2ca	21-60	10YR 5/3 4/3	*2	1	o	sh fr				8.7 ev	

/1 Few fine distinct lime concretions

/2 Many fine & medium lime specks & threads

/3 Many fine & medium 0-2", few medium & coarse 2-10", very few coarse 10-21".

RYARK SERIES

A_1	0-4" -	Brown (10YR 5/3) loamy sand; dark yellowish brown (10YR 4/4) moist; coarse, weak crumb; soft very friable; noncalcareous, neutral, pH 7.2; clear, smooth boundary.
B_21t	4-14" -	Brown (10YR 5/3) sandy loam, 18 percent clay; dark brown (10YR 4/3) moist; coarse, weak prismatic breaking to medium and coarse angular blocky; slightly hard, friable; thin, nearly continuous waxy coatings and a few thick patchy sand bridges; noncalcareous; mildly alkaline, pH 7.6; clear, smooth boundary.
B_22t	14-26" -	Yellowish brown (10YR 5/4) sandy loam, 16 percent clay; dark yellowish brown (10YR 4/4) moist; medium and coarse weak angular blocky; slightly hard, friable; thin, patchy clay films and sand bridges, coats; noncalcareous, mildly alkaline, pH 7.6; clear, smooth boundary.
B_23	26-40" -	Yellowish brown (10YR 5/4) sandy loam, 16 percent clay; dark yellowish brown (10YR 4/4) moist; coarse, weak angular blocky; slightly hard, friable; few thin patchy clay films, sand bridges and coatings on vertical surfaces; noncalcareous, mildly alkaline, pH 7.6; clear, smooth boundary.
C_{ca}	40-60" -	Pale brown (10YR 6/3) sandy loam; yellowish brown (10YR 5/4) moist; massive; slightly hard, friable; violent effervescence, many fine and medium, distinct specks and threads of calcium carbonate; strongly alkaline, pH 8.6.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Ryark Series

VEGETATION-SOIL DESCRIPTION

1. State WY	2. District Rawlins	3. Planning Unit	4. Vegetation—Soil Unit *1 /	5. Soil Map Symbol 8140	6. Surname	7. Date 8 mo 75 yr
8. Area Red Rim	9. County Carbon	10. Location Sec. 4, T. 19N, R 90W	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock Old Wind Deposition
15. Formation Name Basal member of Ft. Union	16. Surface Conditions (percent) Stone — Rock —	17. Land Conditions Alkaline - Saline - Water table > 6'				18. Landform Convex side slope
19. Slope (percent) 7% [ ] Single [x] Complex	20. Aspect Southwest	21. Elevation 7050	22. Present Erosion Type SSF 34 Class Slight			23. Hydrologic Group B
24. Precipitation (in) 10-14" 1st, 2nd, 3rd, 4th	25. Temperature Less than 47°F Air — Soil	26. Frost-free Days > 28°	27. Drainage Class Well	28. Infiltration Mod. rapid	29. Percolation Medium to somewhat rapid	30. ERD — in; 31. AWC — in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-4	10YR 5/3 4/4		ls	clcr	s vfr				7.2 eo	cs
B21t	4-14	10YR 5/3 4/3		18% sl	clpr-m&clabk	sh fr	*2			7.6 eo	cs
B22	14-26	10YR 5/4 4/4		16% sl	m&clabk	sh fr	*3			7.6 eo	cs
B23	26-40	10YR 5/4 4/4		16% sl	clabk	sh fr	*4			7.6 eo	cs
Cca	40-60	10YR 6/3 5/4		sl	m	sh fr	*5			8.6 ev	

*1 Needle & thread, Rabbitbrush, Prairie Junegrass, Big sage, Sandberg Bluegrass

*2 Thin, nearly continuous waxy - few thick patchy sand bridges

*3 Thin, patchy - sand bridges & coats

*4 Few, thin patchy - sand bridges & coatings on vert. surfaces

*5 Many fine distinct and medium spots & threads of calcium carbonate

SKOOTCH SERIES

A_1	0-2"	-	Pale brown (10YR 6/3) sandy loam; dark brown (10YR 4/3) moist; fine and medium, weak crumb; soft, very friable; strongly calcareous; moderately alkaline; clear, smooth boundary. Fifteen percent of surface covered with flat sandstone fragments.
C	2-16"	-	Pale brown (10YR 6/3) sandy loam; dark brown (10YR 4/3) moist; structureless; soft, very friable; strongly calcareous; strongly alkaline; clear, smooth boundary.
Cr	16"+	-	Fragmented yellowish brown calcareous sandstone.

Skootch Series

VEGETATION-SOIL DESCRIPTION

1. State WY	2. District Rawlins	3. Planning Unit --	4. Vegetation-Soil Unit *1 /	5. Soil Map Symbol 8150	6. Surname	7. Date 10 mo 75 yr
8. Area Red Rim	9. County Carbon	10. Location Sec. 18, T. 19N, R. 90W	11. Photo No.	12. Writeup No.	13. File No	14. Parent Rock Sandy Shale
15. Formation Name Ft. Union	16. Surface Conditions (percent) Stone -- Rock 15%	17. Land Conditions Alkaline - Saline Slight Water table None				18. Landform Upland ridgecrest
19. Slope (percent) 0-10% ☐ Single ☒ Complex	20. Aspect --	21. Elevation 7100	22. Present Erosion Type SSF 64 Class Critical			23. Hydrologic Group B -
24. Precipitation (in) 10-14" - 1st, 2nd, 3rd, 4th	25. Temperature 47°F Less than Air -- Soil	26. Frost-free Days --- > 28°	27. Drainage Class Well to somewhat excessive	28. Infiltration Moderate	29. Percolation	30. ERD -- in / 31. AWC --.-- in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-2	10YR 6/3 4/3		sl	f&mlcr	s vfr	0	*2	*3	es	cs
C	2-16	10YR 6/3 4/3		sl	o	s vfr	0			es	cs
Cr	16+	Fragmented yellowish brown sandstone Calcareous									

*1 Needle-leaf sedge, Indian ricegrass, Prairie Junegrass, Rabbitbrush

*2 Many fine & medium 0-2", few medium & coarse 2-10"

*3 15% surface covered with flat sandstone fragments

BLAZON SERIES

A_1	0-2"	-	Brown (10YR 5/3) loam; dark brown (10YR 4/3) moist; fine and medium weak crumb; soft, friable; calcareous; alkaline (pH 8.0); clear, smooth boundary, Flat siltstone fragments cover 15-30 percent of surface.
C_1	2-6"	-	Brown (10YR 5/3) loam; dark brown (10YR 4/3) moist; structureless; soft, friable; violent effervescence; strongly alkaline, pH 8.6; clear, smooth boundary. Flat siltstone fragments 1/2-3/4" wide make up 10 percent of horizon.
C_1ca	6-16"	-	Pale brown (10YR 6/3) loam; brown (10YR 5/3) moist; structureless; soft, friable; violent effervescence, many fine specks of calcium carbonate; strongly alkaline pH 8.6; clear smooth boundary. Few shale platelets.
Cr	16"+	-	Soft calcareous shale.

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Blazon Series

VEGETATION–SOIL DESCRIPTION

1. State WY	2. District Rawlins	3. Planning Unit – –	4. Vegetation–Soil Unit *1 – – – – – – – – – / – – – – – – –	5. Soil Map Symbol 815D	6. Surname – – – – – – – – – – – – – – – – – –	7. Date 10 – mo 75 yr
8. Area – –	9. County Carbon	10. Location Sec. 18 –, T. 18N –, R. 91W –	11. Photo No. – – – – – – – – – – –	12. Writeup No. – – – –	13. File No – – – – – – –	14. Parent Rock Unconsolidated Sandstone

15. Formation Name Ft. Union	16. Surface Conditions (percent) Stone – – Rock – –	17. Land Conditions Alkaline – Saline – Water table >6'	18. Landform Ridgecrest
19. Slope (percent) 12-25 ___ Single _x_ Complex	20. Aspect – – / 21. Elevation 7100	22. Present Erosion Type SSF 64 Class Critical	23. Hydrologic Group B –

24. Precipitation (in) 10-14" – 1st, 2nd, 3rd, 4th	25. Temperature Less than 47°F Air – – Soil	26. Frost-free Days – – – > 28°	27. Drainage Class Well	28. Infiltration Mod. slow	29. Percolation Moderate	30. ERD – – in	31. AWC – – . – in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-2	10YR 5/3 4/3	/2	1	f&mlcr	s fr	0	*5		e	cs
C1	2-6	10YR 5/3 4/3	/3	1	0	s fr				8.6 ev	cs
C1ca	6-16	10YR 6/3 5/3	/4	1	0	s fr				8.6 ev	cs
Cr	16+	Soft, calc, shale								ev	

/1 Gardner's saltbrush, Bird foot sage.

/2 Flat silt stone fragments cover 15-30% of surface

/3 10% 1/2-3/4" flat siltstone fragments

/4 Many fine specks CaCO3 and few shale platelets, 15% ½-3/4" siltstone fragments

/5 Few, medium & coarse to 10"

UNITED STATES
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INTERPRETIVE RATINGS FOR SOIL USES

MAP SYMBOL	SOIL NAME	SUITABILITY					
		DRYLAND FARMING	IRRI-GATION	TOPSOIL	SAND GRAVEL	ROAD FILL	OTHER
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
8060 A-33, B-38	Havre sandy loam, 0-3% slope	Fair; Mod. salinity, climate	Good; some salinity	See ratings in other sections of report	Fair	Good	
8070 B-37, C-42	Rock River sandy loam, 3-12% slope	Fair; climate	V. Good	"	Poor; texture	Good	
8080 B-37, C-42	Cushool sandy loam, 3-12% slope	Fair; climate	Good depth	"	Poor; texture	Good	
8100 A-50	Havre sandy loam, alkaline phase, 0-3% slope	Poor, climate, alkalinity	Poor to fair alkalinity	"	Fair	Good	
8110 BD-41	Worfman sandy loam, 3-12% slope	Poor; climate, shallow	Fair; water-holding capacity	"	Poor; texture	Good	
8110 BD-41	Delphill sandy loam, 3-20% slope	Fair; climate	Good; depth	"	Poor; texture	Good	
8120 CE-38	Spool loamy sand, 12 - 40% slope	Poor; climate, V shallow	Poor; water-holding capacity	"	Fair	Poor	
8120 CE-38	Cothran fine sand, 12-20% slope	Poor; climate V. rapid perme-ability	Poor; water holding capacity	"	Fair	Poor	

UNITED STATES
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INTERPRETIVE RATINGS FOR SOIL USES

MAP SYMBOL (1)	SOIL NAME (2)	SUITABILITY: DRYLAND FARMING (3)	IRRIGATION (4)	TOPSOIL (5)	SAND GRAVEL (6)	ROAD FILL (7)	OTHER (8)
8130 / BD-35	Rock River (Refer to 8070 / B37, C-42)						
8130 / BD-35	Patent loam, 3-20% slope	Fair; climate	V. Good	See ratings in other sections of report	Poor	Good	
8140 / BD-34	Rock River (Refer to 8070 / B-37, C-42)						
8140 / BD-34	Ryark sandy loam, 3-20% slope	Fair; climate	Good, water-holding capacity	"	Poor	Fair to good	
8150 / CD-50, DE-64	Skootch sandy loam, 7-40% slope	Poor; climate shallow	Poor; shallow water-holding capacity	"	Poor	Fair	
8150 / CD-50, DE-64	Blazon sandy loam, 7-40% slope	Poor; climate shallow	Poor; shallow water-holding capacity	"	Poor	Fair	

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

ENGINEERING PROPERTIES OF SOILS
MEASUREMENTS AND INTERPRETATIONS

MAP SYMBOL	SOIL NAME	DEPTH FROM SURFACE OF TYPICAL PROFILE (inches)	DEPTH TO		HYDRO-LOGIC SOIL GROUP	SHRINK-SWELL POTEN-TIAL	CORROSIVITY	
			BED-ROCK	SEASONAL HIGH WATER TABLE (inches)			UNCOATED STEEL	CON-CRETE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8060 A-33,B-38	Havre sandy loam, 0-3% slope	0-30 30-60	60" 60"	Floodplain "	C C	Low Low	Low Low	High High
8070 B-37, C-42	Rock River sandy loam, 3-12% slope	0-4 4-30 30-56	40-60" 40-60" 40-60"	60 60 60	B B C	V Low V Low Low	Low Low Low	Low Low Low
8080 B-37, C-42	Cushool sandy loam, 3-12% slope	0-3 3-18 18-30	20-40" 20-40" 20-40"	60 60 60	B B B	V Low V Low V Low	Low Low Low	Low Low Low
8100 A-50	Havre sandy loam, alkaline phase, 0-3% slope	0-8 8-40	60" 60"	60 60	D D	Low Low	Mod. Mod.	High High
8110 BD-41	Worfman sandy loam, 3-12% slope	0-3 3-17	14-20" 14-20"	60 60	B B	Low Low	Low Low	Low Low
8110 BD-41	Delphill sandy loam, 3-20% slope	0-10 10-28	20-40" 20-40"	60 60	B B	Low Low	Low Low	Low Low
8120 CE-38	Spool loamy sand 12-40% slope	0-8	7-14"	60	A	V Low	Low	Low

UNITED STATES
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BUREAU OF LAND MANAGEMENT

ENGINEERING PROPERTIES OF SOILS
MEASUREMENTS AND INTERPRETATIONS

MAP SYMBOL	SOIL NAME	DEPTH FROM SURFACE OF TYPICAL PROFILE (inches)	DEPTH TO		HYDRO-LOGIC SOIL GROUP	SHRINK-SWELL POTEN-TIAL	CORROSIVITY	
			BED-ROCK	SEASONAL HIGH WATER TABLE (inches)			UNCOATED STEEL	CON-CRETE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8120 CE-38	Cothran fine sand, 12-20% slope	0-60	more than 40"	60	A	V Low	Low	Low
8130 BD-35	Rock River (Refer to 8070 B-37, C-42)							
8130 BD-35	Patent loam, 3-20% slope	0-21	more than 40"	60	B	Low	Low	Low
		21-60	"	60	B	Low	Low	Low
8130 BD-34	Rock River (Refer to 8070 B-37, C-42)							
8140 BD-34	Ryark sandyloam, 3-20% slope	0-26	more than 40"	60	B	Low	Low	Low
		26-40	"	60	B	Low	Low	Low
8150 CD-50, DE-64	Skootch sandyloam, 7-40% slope	0-16	14-20"	60	D	Low	Low	Low
8150 CD-50, DE-64	Blazon loam, 7-40% slope	0-17	14-20"	60	D	Low	Low	Low

A P P E N D I X D

V E G E T A T I O N

Table DI.--Vegetation-soil-water relationships and associated soils data

SYMBOLS: H, HORIZON; DM, DEPTH IN DECIMETERS; VW, VOLUME WEIGHT IN GRAMS PER CUBIC CENTIMETER; SM, SOIL-MOISTURE CONTENT IN GRAMS PER GRAM; PF, LOG OF MOISTURE STRESS IN GRAMS PER SQUARE CENTIMETER; MRC, MOISTURE-RETENTION CAPABILITY AT PF 2.34 IN GRAMS PER GRAM; VMC, VOID-MOISTURE CAPACITY IN GRAMS PER GRAM; SMC, SATURATION-MOISTURE CAPACITY IN GRAMS PER GRAM; VS, VOLUMETRIC SHRINK IN CUBIC CENTIMETERS PER CUBIC CENTIMETER; EC, ELECTRICAL CONDUCTIVITY OF SATURATED SOIL IN MILLIMHOS PER CENTIMETER; PH, LOG OF HYDROGEN CONTENT IN MOLS PER LITER; ROOTS, WEIGHT OF ROOTS CONTAINED PER CUBIC DECIMETER OF SOIL; DET, DETACHABILITY OF SOIL BY FLOWING WATER IN KILOGRAMS PER HOUR FROM A SQUARE METER OF SURFACE; CPR, COARSE PARTICLE RATIO - WEIGHT OF PARTICLES OF DIAMETER GREATER THAN .25 MILLIMETERS DIVIDED BY TOTAL WEIGHT OF SOIL PARTICLES; MW, MOISTURE CONTENT WHEN WET IN GRAMS PER GRAM; MD, MOISTURE CONTENT WHEN DRY IN GRAMS PER GRAM; MDM, MOISTURE STORAGE DEPLETED IN DECIMETERS.

R 1

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	0.75	.190	4.28	.379	0.96	1.04	.35	0.65	6.15	100.6	0.3	.003
	2	1.05	.103	4.06	.184	0.57	0.53	.26	0.52	6.20	13.1	0.5	.001
	3	1.19	.095	4.03	.168	0.46	0.44	.29	0.56	6.37	14.0	0.6	.001
	4	1.28	.113	3.76	.178	0.41	0.53	.34	0.45	6.46	7.7	0.6	.003
	5	1.07	.097	3.73	.152	0.56	0.43	.29	0.49	6.72	5.4	0.6	.002
	6	1.10	.132	3.27	.174	0.54	0.44	.31	0.45	6.71	3.8	1.6	.002
	7	1.16	.141	3.29	.187	0.48	0.47	.34	0.45	6.62	5.2	0.6	.001
	8	1.24	.162	3.15	.205	0.43	0.46	.34	0.53	6.58	10.3	2.2	.001
	9	1.24	.166	2.76	.186	0.43	0.45	.35	0.47	6.64	4.1	1.5	.001
	10	1.11	.152	2.88	.178	0.52	0.41	.33	0.38	6.70	1.5	1.0	.001
	11	1.04	.169	2.38	.172	0.59	0.41	.32	0.35	6.74	1.5	0.8	.001
	12	1.25	.156	2.33	.156	0.42	0.37	.30	0.34	6.81	1.1	0.6	.003
	13	1.25	.171	2.34	.172	0.42	0.40	.31	0.45	6.79	2.8	1.2	.002
	14	1.40	.186	2.33	.187	0.34	0.41	.34	0.38	6.90	1.4	0.6	.001
	15	1.32	.208	2.62	.225	0.38	0.47	.36	0.56	6.96	3.3	1.2	.001
	16	1.56	.176	2.34	.177	0.26	0.41	.34	0.50	7.02	2.2	1.0	.002
	17	1.43	.203	2.34	.204	0.32	0.44	.36	0.53	6.92	6.4	1.4	.001
	18	1.56	.187	1.85	.167	0.26	0.43	.35	0.48	7.11	1.7	0.9	.002
	19	1.53	.180	2.38	.183	0.28	0.43	.35	0.53	7.00	2.7	1.1	.003
	20	1.70	.205	2.24	.200	0.21	0.43	.37	0.48	7.12	1.5	0.7	.002
	21	1.57	.191	2.20	.185	0.26	0.38	.33	0.49	7.08	1.5	1.2	.002
	22	1.45	.212	2.04	.197	0.31	0.41	.32	0.46	7.10	1.2	0.6	.002
	23	1.40	.221	1.96	.203	0.34	0.40	.36	0.46	7.14	1.1	0.9	.002
	24	1.48	.208	2.27	.205	0.30	0.42	.36	0.52	7.04	1.3	0.9	.004
	25	1.53	.202	2.09	.190	0.27	0.42	.35	0.53	7.07	3.0	0.9	.004
	26	1.52	.251	1.85	.224	0.28	0.44	.35	0.48	7.08	1.5	1.4	.002
	27	1.46	.236	1.94	.215	0.31	0.43	.36	0.48	7.08	1.7	1.1	.002
	28	1.52	.210	1.93	.191	0.28	0.41	.35	0.47	7.09	1.7	0.7	.003
	29	1.61	.208	1.92	.189	0.24	0.38	.29	0.45	7.13	2.5	0.7	.006
	30	1.59	.215	1.63	.183	0.25	0.40	.31	0.42	7.17	2.7	1.5	.004
	31	1.60	.258	1.95	.236	0.25	0.45	.34	0.51	6.90	1.3	1.4	.001
	32	1.60	.232	1.88	.208	0.25	0.41	.34	0.47	7.11	1.6	1.3	.002

R 2

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1	1.35	.038	5.76	.304	0.36	0.42	.34	0.76	6.97	9.6	3.7	.008	
2	1.61	.036	5.42	.172	0.25	0.36	.25	0.52	7.28	6.6	5.3	.028	
3	1.62	.051	4.98	.157	0.24	0.37	.27	0.53	7.39	5.2	4.9	.008	
4	1.61	.062	4.94	.187	0.25	0.39	.30	0.56	7.53	3.2	1.8	.010	
5	1.53	.053	4.96	.161	0.28	0.36	.27	0.46	7.58	5.0	2.4	.017	
6	1.59	.056	4.99	.176	0.25	0.35	.25	0.48	7.67	5.4	2.2	.015	
7	1.61	.054	4.98	.168	0.24	0.33	.27	0.47	7.67	3.7	3.1	.018	
8	1.47	.051	4.96	.156	0.30	0.34	.29	0.40	7.86	2.2	1.5	.010	
9	1.48	.052	4.88	.149	0.30	0.32	.26	0.39	7.73	3.6	3.5	.015	
10	1.43	.056	4.87	.158	0.32	0.34	.26	0.51	7.82	3.4	3.9	.018	
11	1.45	.056	4.93	.167	0.31	0.35	.26	0.66	7.79	3.2	9.3	.018	
12	1.42	.053	4.93	.157	0.33	0.35	.27	0.72	7.82	2.3	9.4	.020	
13	1.53	.062	4.83	.173	0.28	0.39	.31	0.91	7.83	2.1	6.0	.013	
14	1.48	.055	4.83	.152	0.30	0.36	.28	0.94	7.85	1.8	7.9	.017	
15	1.49	.060	4.84	.166	0.29	0.40	.29	0.93	7.83	1.8	9.5	.014	
16	1.49	.062	4.78	.166	0.29	0.39	.30	1.25	7.80	1.9	22.4	.012	

R 3

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1	1.32	.024	5.83	.230	0.38	0.33	.25	0.48	7.17	8.5	1.8	.020	
2	1.37	.039	4.99	.121	0.35	0.28	.21	0.36	7.40	6.5	2.3	.021	
3	1.43	.073	4.64	.179	0.32	0.41	.28	0.57	7.58	4.5	3.6	.008	
4	1.44	.069	4.52	.157	0.32	0.40	.30	0.47	7.67	6.5	3.8	.010	
5	1.42	.061	4.57	.143	0.32	0.35	.25	0.42	7.72	6.7	2.4	.013	
6	1.45	.053	4.60	.126	0.31	0.33	.25	0.39	7.81	5.1	7.1	.024	
7	1.44	.049	4.56	.115	0.32	0.33	.25	0.36	7.80	4.0	10.6	.025	
8	1.46	.051	4.57	.118	0.31	0.35	.25	0.35	7.87	3.6	10.8	.027	
9	1.49	.060	4.61	.143	0.29	0.36	.27	0.41	7.79	5.9	4.4	.016	
10	1.51	.058	4.63	.142	0.29	0.34	.25	0.38	7.88	3.9	6.3	.011	
11	1.56	.057	4.67	.141	0.26	0.35	.27	0.37	7.89	2.8	4.6	.021	
12	1.62	.051	4.62	.122	0.24	0.31	.23	0.36	7.93	2.3	10.6	.018	
13	1.71	.047	4.66	.117	0.21	0.31	.22	0.34	7.98	2.3	12.5	.022	
14	1.75	.045	4.70	.115	0.19	0.29	.22	0.31	8.02	2.0	6.1	.023	
15	1.74	.049	4.11	.090	0.20	0.31	.24	0.37	8.02	2.7	9.3	.020	
16	1.74	.048	4.66	.119	0.20	0.31	.25	0.34	8.05	3.2	5.6	.013	

R 4

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1	1.21	.057	5.47	.289	0.45	0.47	.36	0.76	7.30	2.5	9.7	.010	
2	1.36	.100	4.88	.287	0.36	0.55	.42	0.71	7.42	2.4	5.6	.003	
3	1.53	.115	4.58	.269	0.28	0.54	.43	0.71	7.58	1.9	7.7	.002	
4	1.73	.117	4.54	.270	0.20	0.53	.40	0.79	7.62	1.0	11.2	.001	
5	1.79	.122	4.35	.252	0.18	0.54	.43	1.79	7.59	1.4	15.5	.001	
6	1.76	.122	4.45	.266	0.19	0.56	.46	2.43	7.42	0.9	31.3	.001	
7	1.70	.121	4.53	.277	0.21	0.56	.45	2.27	7.36	0.3	20.1	.000	
8	1.63	.126	4.59	.298	0.24	0.58	.44	2.38	7.23	0.3	51.8	.000	
9	1.76	.133	4.48	.295	0.19	0.57	.43	2.63	7.09	0.1	18.6	.000	
10	1.82	.129	4.54	.297	0.17	0.55	.40	2.17	7.00	0.1	20.7	.000	
11	1.83	.124	4.52	.283	0.17	0.55	.38	2.05	6.80	0.0	23.7	.000	
12	1.81	.129	4.49	.287	0.18	0.55	.40	1.79	6.96	0.1	21.3	.000	
13	1.78	.131	4.49	.292	0.19	0.54	.38	1.70	6.88	0.0	23.9	.000	
14	1.81	.138	4.47	.305	0.18	0.54	.39	1.79	7.00	0.1	25.2	.000	
15	1.75	.141	4.48	.314	0.20	0.58	.42	1.56	7.02	0.1	30.2	.000	
16	1.75	.137	4.51	.311	0.20	0.60	.44	1.56	7.10	0.1	36.7	.000	

R 5

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1		1.21	.041	4.73	.106	0.45	0.31	.17	0.38	7.17	18.3	0.9	.042
2		1.28	.055	4.82	.152	0.41	0.28	.18	0.48	7.40	23.2	0.6	.041
3		1.52	.061	4.74	.158	0.28	0.30	.22	0.77	7.53	9.0	0.8	.037
4		1.72	.054	4.66	.133	0.20	0.26	.17	0.96	7.76	9.9	4.8	.042
5		1.95	.051	4.58	.119	0.14	0.27	.19	0.94	7.88	11.5	18.7	.047
6		1.80	.064	4.30	.128	0.18	0.30	.18	1.47	7.95	5.6	10.0	.045
7		1.68	.055	4.34	.114	0.22	0.26	.19	1.35	8.07	1.3	25.3	.045
8		1.52	.070	4.39	.148	0.26	0.28	.17	1.32	8.10	3.9	31.7	.042
9		1.84	.066	4.37	.138	0.17	0.28	.21	1.67	8.07	4.5	4.8	.042
10		1.74	.056	4.44	.122	0.20	0.29	.21	1.43	8.02	6.3	9.7	.048
11		1.83	.058	4.36	.120	0.17	0.25	.22	1.32	8.21	2.7	6.3	.041
12		1.80	.106	4.49	.237	0.18	0.39	.33	2.17	8.29	5.0	0.6	.018
13		2.01	.103	4.28	.206	0.12	0.36	.26	2.50	8.33	8.8	27.1	.029
14		1.99	.079	4.29	.158	0.12	0.32	.23	2.27	8.44	4.9	47.6	.039
15		1.86	.103	4.33	.210	0.16	0.38	.32	2.50	8.68	3.2	9.5	.030
16		1.85	.094	4.28	.187	0.16	0.36	.30	2.50	8.81	1.8	1.6	.037
17		1.62	.069	4.23	.135	0.17	0.30	.21	2.78	8.71	1.1	3.1	.051
18		1.69	.103	4.28	.205	0.21	0.10	.36	3.68	8.68	0.8	1.2	.027
19		1.81	.079	4.25	.155	0.17	0.31	.21	3.21	8.58	1.3	1.1	.043
20		1.70	.079	4.30	.159	0.21	0.31	.20	3.52	8.54	1.6	20.5	.046
21		1.80	.097	4.24	.188	0.18	0.34	.28	4.31	8.27	0.8	18.1	.029
22		1.71	.105	4.20	.202	0.21	0.38	.29	4.46	8.52	1.7	15.3	.031
23		1.69	.102	4.25	.200	0.21	0.38	.27	4.31	8.56	2.8	15.5	.034
24		1.80	.092	4.23	.180	0.18	0.32	.27	3.97	8.57	1.3	25.2	.040
25		1.71	.084	4.25	.165	0.21	0.34	.25	3.85	8.52	2.5	25.5	.047
26		1.88	.105	4.21	.202	0.15	0.36	.30	4.46	8.57	1.7	23.0	.036
27		1.75	.099	4.26	.195	0.19	0.36	.26	4.03	8.53	1.4	20.9	.037
28		1.79	.092	4.28	.183	0.18	0.33	.26	3.91	8.52	2.1	23.4	.042
29		1.63	.084	4.25	.165	0.24	0.31	.22	3.85	8.59	0.9	33.9	.041
30		1.51	.067	4.32	.135	0.28	0.28	.18	2.98	8.33	0.6	47.8	.050
31		1.44	.057	4.24	.112	0.32	0.24	.16	2.84	8.46	0.6	59.6	.051
32		1.74	.056	4.26	.112	0.20	0.25	.15	2.50	8.51	0.9	70.0	.058
33		2.01	.064	4.17	.120	0.12	0.28	.19	2.78	8.53	2.1	67.1	.050
34		2.17	.066	4.22	.127	0.08	0.27	.17	2.91	8.41	2.2	38.5	.047
35		2.18	.062	4.24	.121	0.08	0.27	.18	2.75	8.52	3.2	54.8	.052
36		1.93	.062	4.25	.121	0.14	0.28	.16	2.69	8.50	6.5	100.3	.052
37		2.04	.061	4.51	.137	0.11	0.25	.15	2.66	8.48	3.1	56.8	.053
38		1.74	.068	4.33	.139	0.20	0.30	.20	3.05	8.59	3.4	46.9	.046
39		1.78	.075	4.28	.149	0.18	0.28	.23	3.21	8.63	0.8	35.0	.048
40		1.48	.090	4.40	.192	0.30	0.32	.22	4.10	8.62	0.5	15.7	.038
41		1.48	.072	4.18	.137	0.30	0.26	.21	3.25	8.57	0.7	25.9	.043
42		1.80	.081	4.24	.160	0.18	0.32	.23	3.68	8.61	2.4	26.6	.039
43		1.84	.073	4.19	.139	0.17	0.27	.19	3.38	8.63	0.9	31.1	.044
44		1.52	.064	4.24	.126	0.28	0.26	.17	3.13	8.61	0.3	42.4	.048
45		1.85	.069	4.16	.130	0.16	0.25	.19	3.21	8.58	0.6	45.1	.044
46		2.07	.064	4.35	.132	0.11	0.27	.15	3.09	8.44	2.5	56.0	.045
47		2.08	.074	4.15	.139	0.10	0.30	.20	3.47	8.49	3.3	40.2	.045
48		2.08	.080	4.07	.143	0.10	0.27	.18	3.33	8.53	1.7	38.7	.047

H DM	VW	SM	PF	MRC	VMC	SMC	VS	FC	PH	ROOTS	DET	CPR
R 6												
1	1.20	.072	4.82	.197	0.45	0.41	.27	0.74	6.95	35.8	3.0	.013
2	1.27	.113	4.23	.219	0.41	0.52	.31	0.74	6.85	70.0	1.7	.005
3	1.31	.111	4.16	.209	0.39	0.49	.34	0.77	6.98	94.6	0.8	.005
4	1.43	.115	4.23	.224	0.32	0.49	.35	0.81	7.08	5.4	4.2	.003
5	1.57	.095	4.26	.187	0.26	0.42	.32	0.68	7.32	5.3	2.8	.006
6	1.55	.091	4.22	.176	0.27	0.41	.32	0.64	7.42	2.1	9.5	.003
7	1.53	.101	4.25	.197	0.28	0.45	.34	0.68	7.35	2.5	6.3	.002
8	1.37	.106	4.22	.205	0.35	0.47	.34	0.69	7.45	2.2	3.6	.002
9	1.54	.111	4.22	.215	0.27	0.48	.33	0.71	7.32	12.8	2.4	.003
10	1.61	.137	4.17	.258	0.25	0.57	.46	0.77	7.52	0.7	12.5	.003
11	1.59	.149	4.16	.279	0.25	0.59	.44	0.89	7.68	0.5	16.2	.003
12	1.53	.139	4.13	.256	0.28	0.54	.40	0.86	7.78	0.5	3.9	.011
13	1.59	.165	4.17	.313	0.25	0.64	.48	1.16	7.60	1.4	22.9	.001
14	1.88	.170	4.16	.320	0.15	0.65	.50	1.19	7.73	1.3	17.3	.002
15	1.78	.148	4.26	.294	0.19	0.59	.47	1.35	7.60	5.1	9.1	.004
16	1.78	.169	4.36	.352	0.19	0.66	.48	1.32	7.78	0.9	10.2	.002
R 7												
1	1.26	.076	5.48	.393	0.41	0.45	.32	0.63	6.40	20.1	0.6	.023
2	1.29	.102	4.83	.283	0.40	0.46	.33	0.60	6.22	3.2	2.3	.013
3	1.52	.098	4.70	.250	0.28	0.43	.34	0.63	6.65	1.3	2.5	.014
4	1.58	.092	4.69	.232	0.26	0.41	.32	0.75	6.65	3.7	1.3	.019
5	1.60	.081	4.72	.209	0.25	0.37	.30	0.64	6.95	2.5	1.3	.020
6	1.60	.086	4.63	.208	0.25	0.36	.29	0.68	7.18	1.0	2.5	.021
7	1.54	.085	4.25	.167	0.27	0.39	.29	1.22	6.98	3.4	13.3	.029
8	1.57	.083	4.50	.187	0.26	0.38	.28	1.32	7.08	1.7	2.7	.032
9	1.44	.079	4.56	.183	0.32	0.35	.25	1.64	7.12	2.1	4.8	.032
10	1.44	.050	4.54	.115	0.32	0.26	.15	1.09	7.22	1.0	23.6	.046
R 8												
1	1.20	.056	5.24	.219	0.46	0.40	.20	0.53	7.08	22.2	0.6	.028
2	1.44	.056	4.62	.135	0.32	0.38	.14	0.32	7.40	7.0	2.4	.038
3	1.75	.065	4.42	.139	0.19	0.37	.16	0.36	7.42	2.7	27.3	.033
4	1.95	.070	4.29	.141	0.14	0.36	.18	0.40	7.38	1.6	98.5	.049
5	2.05	.070	4.02	.124	0.11	0.36	.18	0.32	7.55	2.0	49.3	.060
6	2.05	.083	3.63	.124	0.11	0.35	.17	0.35	7.65	1.0	109.4	.050
R 9												
1	1.39	.041	4.14	.076	0.34	0.26	.11	0.28	7.18	3.3	26.7	.058
2	1.43	.051	4.00	.089	0.32	0.28	.14	0.36	7.15	4.4	8.7	.059
3	1.65	.046	4.23	.089	0.23	0.26	.10	0.38	7.02	4.0	4.6	.071
4	1.79	.047	4.05	.084	0.18	0.29	.12	0.29	7.15	2.4	10.4	.064
5	1.95	.047	4.11	.086	0.14	0.31	.15	0.26	7.40	2.0	12.7	.074
6	1.78	.046	4.28	.093	0.18	0.28	.12	0.26	7.40	2.8	23.8	.072
7	2.00	.061	4.21	.117	0.12	0.32	.14	0.26	7.38	3.6	13.2	.073
8	2.07	.043	4.00	.076	0.11	0.26	.12	0.21	7.45	2.0	30.3	.075
9	2.07	.040	4.14	.075	0.11	0.28	.13	0.27	7.35	9.0	39.7	.072

R10

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1	1.78	.038	5.24	.146	0.18	0.25	.17	0.40	7.21	4.4	3.6	.046
2	1.74	.051	5.00	.162	0.20	0.29	.22	0.46	7.38	3.7	3.5	.030
3	1.59	.073	4.61	.174	0.25	0.36	.28	0.47	7.50	3.1	4.7	.021
4	1.56	.080	4.56	.187	0.26	0.37	.29	0.47	7.50	1.8	4.4	.029
5	1.60	.087	4.59	.205	0.25	0.40	.31	0.47	7.62	2.4	3.3	.012
6	1.71	.084	4.65	.206	0.21	0.42	.33	0.46	7.73	3.0	1.7	.016
7	1.73	.091	4.56	.212	0.20	0.44	.31	0.50	7.82	2.7	2.8	.011
8	1.66	.095	4.55	.219	0.22	0.48	.38	0.67	7.89	2.1	4.1	.008
9	1.55	.085	4.68	.212	0.27	0.43	.36	0.86	7.83	1.4	6.2	.008
10	1.44	.081	4.75	.212	0.32	0.42	.37	0.96	8.01	1.1	8.0	.009
11	1.42	.077	4.71	.195	0.33	0.40	.37	1.04	7.93	0.8	10.5	.007
12	1.52	.062	4.75	.163	0.28	0.36	.31	0.94	8.03	1.0	25.3	.012
13	1.61	.048	4.65	.119	0.24	0.31	.24	0.83	7.94	0.8	23.9	.017
14	1.91	.043	4.72	.111	0.15	0.26	.22	0.86	7.81	0.4	20.7	.035
15	1.91	.047	4.85	.131	0.15	0.23	.15	2.17	7.60	0.3	24.6	.058

R11

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1	1.33	.027	5.17	.098	0.37	0.25	.15	0.27	6.76	11.3	2.0	.067
2	1.67	.039	4.61	.094	0.22	0.24	.17	0.27	7.10	4.6	5.1	.065
3	1.76	.060	4.51	.136	0.19	0.30	.20	0.41	7.17	4.4	12.6	.059
4	1.78	.043	4.51	.097	0.18	0.25	.15	0.36	7.38	0.8	46.0	.069
5	1.67	.037	4.48	.082	0.22	0.24	.15	0.19	7.60	0.9	12.7	.071
6	1.72	.037	4.48	.083	0.20	0.22	.13	0.21	7.60	1.2	18.9	.070
7	1.81	.051	4.29	.103	0.17	0.25	.20	0.24	7.68	0.6	13.3	.061
8	1.67	.052	4.25	.101	0.22	0.26	.18	0.25	7.72	0.9	10.1	.065
9	1.65	.056	4.16	.105	0.23	0.26	.18	0.23	7.78	0.9	13.6	.063
10	1.57	.051	4.13	.095	0.26	0.25	.17	0.22	7.76	0.7	13.1	.063
11	1.46	.050	4.30	.101	0.31	0.24	.17	0.23	7.81	0.6	13.7	.059
12	1.47	.090	4.27	.179	0.30	0.36	.27	0.39	8.07	1.1	3.0	.036
13	1.70	.074	4.17	.140	0.21	0.30	.24	0.38	8.14	1.8	3.1	.048
14	1.84	.055	4.31	.112	0.17	0.26	.17	0.28	8.27	1.0	5.8	.058
15	1.85	.049	4.37	.102	0.16	0.24	.16	0.31	8.28	0.5	11.0	.059
16	1.85	.046	4.44	.101	0.16	0.23	.15	0.40	8.15	0.4	12.8	.064

APPENDIX E

STUDY SITE HYDROLOGY

TABLE E1

Chemical analyses for waters of Separation Creek and tributaries

09216525 - SEPARATION C AT UPPER STATION NR RINER WYO

WATER QUALITY DATA

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)
OCT , 1975												
31...	0830	.40	7.3	--	--	78	82	170	3.3	350	0	570
NOV												
17...	1315	.52	8.8	30	--	130	110	200	5.5	540	0	750
JAN , 1976												
20...	1400	.20	9.5	30	--	120	91	190	2.9	542	--	590
MAR												
10...	1400	.32	8.7	70	--	110	120	180	7.8	423	0	790
29...	1520	4.0	8.3	30	--	90	84	110	7.2	347	0	500
APR												
02...	1530	14	4.5	80	70	39	35	43	5.9	161	0	200
MAY												
13...	0800	12	8.6	40	--	64	44	40	3.8	280	0	200
JUL												
01...	1440	1.6	5.2	20	--	83	68	80	4.1	360	0	320
OCT												
07...	1500	.41	6.0	40	--	43	32	350	3.0	347	0	610
28...	1730	1.5	7.3	60	10	41	30	390	2.5	375	13	670

DATE	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED ORTHO PHOSPHATE (PO4) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	DISSOLVED BORON (B) (UG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	DISSOLVED OXYGEN (MG/L)	TURBIDITY (JTU)	TEMPERATURE (DEG C)
OCT , 1975												
31...	18	.6	--	--	.02	--	1100	1630	8.1	--	--	2.0
NOV												
17...	22	.4	.02	--	--	160	1490	2000	8.2	--	--	12.0
JAN , 1976												
20...	17	.4	.20	--	--	110	1290	1700	--	--	--	.0
MAR												
10...	26	.4	.11	--	.15	200	1450	1850	6.3	10.4	45	1.0
29...	16	.3	.00	.00	--	130	987	1350	8.1	--	--	.0
APR												
02...	6.9	.1	.02	.03	4.4	90	414	630	8.0	--	550	3.0
MAY												
13...	7.5	.3	.06	.03	--	90	507	760	8.2	8.4	--	8.0
JUL												
01...	10	.4	.01	.09	--	140	748	1060	8.4	8.4	20	21.0
OCT												
07...	37	1.0	--	--	.11	190	1250	2000	8.5	9.9	50	9.5
28...	44	.9	.14	.00	.08	210	1380	--	8.8	--	--	2.0

TABLE E1

Chemical analyses for waters of Separation Creek and tributaries--continued

09216527 - SEPARATION C NR RINER WYO

WATER QUALITY DATA

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)
MAR , 1976												
01...	1715	2.5	2.9	120	--	29	20	36	6.3	124	0	120
10...	1145	.69	7.1	120	--	96	87	150	7.0	357	0	620
24...	0900	1.0	5.5	40	--	61	49	68	6.2	233	0	290
29...	1730	6.0	6.9	20	--	96	91	110	7.2	349	--	540
APR												
02...	1330	28	--	40	70	33	30	33	5.8	141	0	--
21...	0900	6.1	7.4	30	--	95	92	110	4.8	370	0	530
MAY												
13...	1030	11	8.0	10	--	64	48	43	3.8	274	3	220
JUN												
21...	1300	3.0	6.2	20	--	60	49	46	4.1	301	0	220
JUL												
01...	1615	.87	4.3	10	--	88	72	80	4.4	384	0	330

DATE	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED ORTHO PHOSPHATE (PO4) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	DISSOLVED BORON (B) (UG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	DISSOLVED OXYGEN (MG/L)	TURBIDITY (JTU)	TEMPERATURE (DEG C)
MAR , 1976												
01...	5.8	.1	.13	--	.69	80	282	450	8.0	10.2	380	.0
10...	20	.3	.15	--	.15	160	1160	1580	8.9	9.1	25	1.0
24...	11	.2	--	--	.18	50	606	990	7.8	10.2	62	.5
29...	16	.2	.01	.00	--	110	1040	1400	8.2	--	--	.0
APR												
02...	--	--	.06	.00	1.6	100	342	525	8.0	--	400	1.5
21...	17	.2	.00	.03	.13	110	1040	1390	8.2	--	47	5.0
MAY												
13...	8.2	.3	.00	.00	--	90	533	780	8.4	9.0	--	8.5
JUN												
21...	9.1	.3	--	--	.12	110	543	810	8.3	7.5	45	18.0
JUL												
01...	11	.4	.01	.09	--	120	780	1090	8.5	8.9	10	21.0

TABLE E I

Chemical analyses for waters of Separation Creek and tributaries--continued

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)
413753107333601 - SITE S-27 (LAT 41 37 53 LONG 107 33 36.01)												
APR . 1976												
29...	1645	6.0	7.1	20	--	87	83	100	7.0	342	0	480
MAY												
13...	0930	11	8.3	30	--	62	45	42	4.0	278	0	200
JUL												
01...	1530	1.6	4.9	10	--	80	70	100	4.5	365	0	400
414017107325701 - SEPARATION CREEK TRIBUTARY BEL GAGE NR RINER WY (LAT 41 40 17 LONG 107 32 57.01)												
MAR . 1976												
30...	1600	.01	4.0	60	--	24	5.0	7.2	7.7	117	0	8.1
414106107304001 - LARSON DRAW NR COMMAND CENTER (LAT 41 41 06 LONG 107 30 40.01)												
APR . 1976												
01...	1730	.60	2.7	30	--	11	2.9	1.6	4.6	64	0	3.9
414122107320101 - SITE S-32 (LAT 41 41 22 LONG 107 32 01.01)												
APR . 1976												
29...	1715	6.0	6.4	40	--	81	83	86	7.3	247	0	510
MAY												
13...	1230	10	7.8	20	--	70	65	53	4.3	302	2	280
JUL												
01...	1720	.50	2.8	10	--	110	150	100	5.4	382	0	740
414515107281501 - SITE S-39 (LAT 41 45 15 LONG 107 28 15.01)												
MAY . 1976												
13...	1330	7.0	7.2	40	--	83	91	82	7.0	372	0	420
JUL												
01...	1800	.68	2.9	20	--	68	110	100	10	396	0	450
APR . 1976												
07...	1530	40	7.8	60	--	63	48	59	9.9	191	0	330
MAY												
13...	1415	6.0	7.1	20	--	63	92	8[illegible]	7.3	376	0	420
JUL												
01...	1830	.02	.3	10	--	54	110	120	14	281	6	510
414637107265201 - SITE S-41 (LAT 41 46 37 LONG 107 26 52.01)												
APR . 1976												
07...	1530	40	7.2	60	--	63	48	59	9.9	191	0	330
MAY												
13...	1415	6.0	7.1	20	--	63	92	64	7.3	376	0	420
JUL												
01...	1830	.02	.3	10	--	54	110	120	14	281	6	510

DATE	TIME	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED ORTHO PHOSPHATE (PO4) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	DISSOLVED BORON (B) (UG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	DISSOLVED OXYGEN (MG/L)	TURBIDITY (JTU)	TEMPERATURE (DEG C)
413753107333601 - SITE S-27 (LAT 41 37 53 LONG 107 33 36.01)													
APR . 1976													
29...	1645	16	.3	.00	.00	--	110	949	1300	8.3	--	--	.5
MAY													
13...	0930	7.8	.3	.00	.00	--	50	507	760	8.3	8.5	--	6.5
JUL													
01...	1530	11	.4	.01	.09	--	130	651	1170	6.5	7.9	10	22.5
414017107325701 - SEPARATION CREEK TRIBUTARY BEL GAGE NR RINER WY (LAT 41 40 17 LONG 107 32 57.01)													
MAR . 1976													
30...	1600	2.0	.1	.10	--	--	60	116	195	8.0	--	--	5.0
414106107304001 - LARSON DRAW NR COMMAND CENTER (LAT 41 41 06 LONG 107 30 40.01)													
APR . 1976													
01...	1730	1.5	.1	.08	--	--	10	60	100	7.4	--	--	[illegible]
414122107320101 - SITE S-32 (LAT 41 41 22 LONG 107 32 01.01)													
APR . 1976													
29...	1715	13	.2	.00	.00	--	110	909	1320	8.2	--	--	2.5
MAY													
13...	1230	9.4	.3	.00	.00	--	100	641	940	8.4	8.6	--	11.5
JUL													
01...	1720	13	.4	.01	.06	--	190	1310	1650	8.4	9.1	4	23.0
414515107281501 - SITE S-39 (LAT 41 45 15 LONG 107 28 15.01)													
MAY . 1976													
13...	1330	13	.3	.00	.03	--	140	887	1200	8.4	12.0	--	18.0
JUL													
01...	1800	16	.3	.04	.05	--	180	953	1350	8.5	8.3	2	21.5
APR . 1976													
07...	1530	14	.2	.00	.00	--	110	556	950	8.0	--	--	5.0
MAY													
13...	1415	14	.3	.00	.00	--	150	893	1350	8.3	10.0	--	16.5
JUL													
01...	1830	21	.4	.01	--	--	130	974	1350	9.1	12.0	1	23.0
414637107265201 - SITE S-41 (LAT 41 46 37 LONG 107 26 52.01)													
APR . 1976													
07...	1530	14	.2	.00	.00	--	110	556	950	8.0	--	--	5.0
MAY													
13...	1415	14	.3	.00	.00	--	150	893	1350	8.3	10.0	--	16.5
JUL													
01...	1830	21	.4	.01	--	--	130	974	1350	9.1	12.0	1	23.0

TABLE E2

Trace metal analyses for waters of Separation Creek

DATE	DIS-SOLVED ALUM-INUM (AL) (UG/L)	TOTAL ALUM-INUM (AL) (UG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS-SOLVED BERYL-LIUM (BE) (UG/L)	TOTAL BERYL-LIUM (BE) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	TOTAL CAD-MIUM (CD) (UG/L)	DIS-SOLVED CHRO-MIUM (CR) (UG/L)	TOTAL CHRO-MIUM (CR) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)
09216525 - SEPARATION C AT UPPER STATION NR RINER WYO (LAT 41 37 52 LONG 107 32 27)												
APR , 1976												
02...	0	23000	0	34	0	0	0	<10	0	40	1	50
OCT												
07...	--	3000	--	3	--	0	--	10	--	0	--	<10
09216527 - SEPARATION C NR RINER WYO (LAT 41 41 22 LONG 107 32 00)												
MAR , 1976												
01...	--	--	--	--	--	--	--	--	--	--	--	--
18...	60	26000	0	26	10	10	0	<10	0	40	4	60
24...	--	2600	--	2	--	10	--	<10	--	20	--	20
APR												
02...	0	14000	0	12	0	0	0	<10	0	40	1	20

DATE	TOTAL IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	DIS-SOLVED MERCURY (HG) (UG/L)	TOTAL MERCURY (HG) (UG/L)	TOTAL MAN-GANESE (MN) (UG/L)	DIS-SOLVED MOLYB-DENUM (MO) (UG/L)	TOTAL MOLYB-DENUM (MO) (UG/L)	DIS-SOLVED SELE-NIUM (SE) (UG/L)	TOTAL SELE-NIUM (SE) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)
09216525 - SEPARATION C AT UPPER STATION NR RINER WYO (LAT 41 37 52 LONG 107 32 27)												
APR , 1976												
02...	42000	0	<100	.0	.0	1400	1	2	0	2	0	200
OCT												
07...	3500	--	<100	--	.0	60	--	10	--	1	--	20
09216527 - SEPARATION C NR RINER WYO (LAT 41 41 22 LONG 107 32 00)												
MAR , 1976												
01...	--	--	--	--	--	--	--	--	--	0	--	--
18...	37000	2	<100	.0	.0	950	0	1	0	1	0	200
24...	3400	--	<100	--	.0	100	--	2	--	0	--	30
APR												
02...	23000	0	<100	.0	.0	710	2	2	0	1	10	100

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TABLE E3

Suspended sediment and turbidity data

Date	Time	Temp (°C)	Instantaneous discharge (cfs)	Suspended sediment concentration (mg/l)	Suspended sediment discharge (Tons/day)	Turbidity (JTU)	Suspended fall diam. (% finer than 62 microns)
413507107255601	Separation Creek, 20.4 miles above gage, near Riner, Wyoming (Site S-6)						
07-01-76	0940	15.0	0.64	12	0.02	4	80
09-02	1130	15.0	.19	88	.05	20	75
11-07	1315	6.5	.04	19	.00	10	63
413349107272901	Separation Creek, 18.7 miles above gage, near Riner, Wyoming (Site S-8)						
07-01-76	1030	16.0	.94	11	.03	3	64
09-02	1330	15.0	.01	52	.00	10	74
413239107291201	Separation Creek, 17.1 miles above gage, near Riner, Wyoming (Site S-10)						
03-29-76	1345	.0	.25	60	.04	--	50
07-01	1115	17.0	1.3	18	.06	2	64
09-02	1500	18.0	.01	158	.00	30	62
11-07	1345	--	.05	35	.00	4	71
413404107311001	Separation Creek, 13.9 miles above gage, near Riner, Wyoming (Site S-14)						
07-01-76	1210	19.5	1.8	56	.27	20	95
09-02	1615	22.0	.02	92	.00	20	68
11-07	1430	--	.20	54	.03	3	64
413731107285101	Separation Creek, 8.7 miles above gage, near Riner, Wyoming (Site S-20a)						
03-29-76	1430	.0	1.5	11	.04	--	30
07-01	1245	19.0	1.8	30	.15	1	69
11-07	1450	--	.03	22	.00	2	46

TABLE E3

·Suspended sediment and turbidity data--Continued

Date	Time	Temp (°C)	Instan-taneous discharge (cfs)	Suspended sediment concentration (mg/1)	Suspended sediment discharge (Tons/day)	Turbidity (JTU)	Suspended fall diam. (% finer than 62 microns)
41373110728510 2	Sixteen Mile Draw, below dam at mouth, near Riner, Wyoming (Site S-20b)						
03-29-76	1440	.0	1.5	30	.12	--	89
07-01	1250	22.0	.08	36	.01	6	89
413737107285103	Separation Creek, 8.6 miles above gage, near Riner, Wyoming (Site S-20c)						
03-29-76	1450	.0	3.0	24	.19	--	57
07-01	1300	20.0	1.9	52	.27	1	81
413752107322701 (09216525)	Separation Creek at upper station, near Riner, Wyoming (Site S-25)						
07-24-75	1545	25.0	.10	29	.01	--	--
11-17	1315	12.0	.52	242	.34	--	--
02-10-76	1200	.0	.20	32	.02	--	--
03-10	1400	1.0	.32	147	.13	--	93
03-20	1100	.0	2.0	75	.40	50	94
03-29	1520	.0	4.0	546	5.9	--	92
04-02	1530	.0	15	2,520	102	550	18
04-21	0800	4.0	6.1	1,470	24	--	--
05-11	1615	13.0	12	346	11	--	82
06-07	1045	--	--	175	--	--	94
06-07	1245	24.0	3.5	148	1.4	50	81
07-01	1440	21.0	1.6	105	.47	20	86
07-12	1145	22.0	.10	49	.01	6	78
413753107333601	Separation Creek, 2.8 miles above gage, near Riner, Wyoming (Site S-27)						
03-29-76	1645	.5	6.0	632	10	--	97
07-01	1530	22.5	1.6	70	.30	10	93

TABLE E3

Suspended sediment and turbidity data--Continued

Date	Time	Temp (°C)	Instan-taneous discharge (cfs)	Suspended sediment concentration (mg/l)	Suspended sediment discharge (Tons/day)	Turbidity (JTU)	Suspended fall diam. (% finer than 62 microns)
413938107332801 (09216527) Separation Creek near Riner, Wyoming (Site S-29)							
03-09-76	1845	.5	.80	140	.30	20	44
03-10	1145	1.0	.69	32	.06	25	--
03-18	1515	.0	16	1,800	78	--	99
03-18	1630	.0	16	1,870	81	760	--
03-19	0945	.0	3.9	380	4.0	--	96
03-19	1615	.0	3.8	212	2.2	--	98
03-20	1210	.0	5.0	204	2.8	170	97
03-23	1700	1.5	6.6	339	6.0	--	97
03-29	1730	.0	6.0	487	7.9	--	95
03-30	1750	1.5	3.5	496	4.7	--	95
04-02	1330	1.5	28	971	73	400	--
04-06	0850	.0	37	692	69	350	--
04-07	1405	3.0	6.9	454	8.5	--	90
04-13	1815	6.5	20	532	29	--	98
04-21	0900	5.0	6.1	234	3.9	47	97
05-11	1500	13.0	8.7	256	6.0	100	99
06-07	1045	15.0	4.9	175	2.3	95	94
06-09	1630	--	--	220	--	--	98
06-23	1100	13.0	3.1	156	1.3	40	97
06-30	1700	19.5	.87	102	.24	5	83
07-01	1615	21.0	.87	94	.22	10	65
413937107332301 Separation Creek Rill A2R, below gage, near Riner, Wyoming							
02-09-76	1600	.0	.01	736	.02	--	--
03-09	1750	.5	.01	403	.01	440	--
413940107333001 Separation Creek Rill A1L, below gage, near Riner, Wyoming							
02-09-76	1610	.0	.05	3,490	.47	--	--

TABLE E3

Suspended sediment and turbidity data--Continued

Date	Time	Temp (°C)	Instantaneous discharge (cfs)	Suspended sediment concentration (mg/l)	Suspended sediment discharge (Tons/day)	Turbidity (JTU)	Suspended fall diam. (% finer than 62 microns)
414106107304001	Larson Draw tributary to Separation Creek, near Riner, Wyoming						
04-01-76	1730	.0	.60	6,210	10	--	83
414122107320101	Separation Creek, 3.2 miles below gage, near Riner, Wyoming (Site S-32)						
03-29-76	1715	2.5	6.0	100	1.6	--	80
04-06	1215	3.0	--	555	--	280	98
07-01	1720	23.0	.50	22	.03	4	90
414515107280001	Separation Cr, 9.9 mi below gage, at UPRR crossing, nr Riner, WY (Site S-39)						
07-01-76	1800	21.5	.08	20	.00	2	90
414637107265201	Separation Cr, 11.5 mi below gage at I-80 crossing, nr Riner, WY (Site S-41)						
07-01-76	1830	23.0	.02	18	.00	1	73

Table E4.--Periphyton and phytoplankton list by genera

Periphyton

Green algae

Ankistrodesmus
Mougeotia
Spirogyra
Ulothrix

Blue green algae

Anabaena
Lyngbya
Oscillatoria

Diatoms

Achnanthes
Amphora
Caloneis
Cocconeis
Cymatopleura
Cymbella
Diploneis
Epithemia
Fragilaria
Gomphonema
Gyrosigma
Hantzschia
Meridion
Navicula
Nitzschia
Pinnularia
Rhoiocosphenia
Rhopalodia
Stauroneis
Surirella
Synedra

Euglenoids

Euglena

Flagellates

Tribonema

Phytoplankton

Green algae

Ankistrodesmus
Carteria
Chlamydomonas
Chlorella
Cosmarium
Scenedesmus
Spaerellopis

Blue green algae

Anabaena
Anacystis
Lyngbya
Oscillatoria

Diatoms

Achnanthes
Amphiprora
Amphora
Cyclotella
Cymbella
Epithemia
Fragilaria
Gomphonema
Gyrosigma
Hantzschia
Melosira
Meridion
Navicula
Nitzschia
Pinnularia
Rhoiocosphenia
Rhopalodia
Synedra

Euglenoids

Euglena
Trachelomonas

Table E5.--Benthic invertebrate list by family

<u>Benthic invertebrates</u>

Agrionidae (Dragon fly)	Gerridae (Water Strider)
Baetidae (May fly)	Glossiphoniidae (Leeches)
Ceratopogonidae (Biting Midge)	Hydracarina (Mite)
Chironomidae (Midge)	Limnephilidae (Caddis fly)
Corixidae (Water Boatman)	Perlodidae (Stone fly)
Culicidae (Mosquito & Phantom Midge)	Physidae (Pouch Snail)
Dytiscidae (Predaceous Diving Beetle)	Sphaeriidae (Fingernail Clams)
Gamaridae (Scuds)	Tipuliidae (Crane fly)

Table E6.--Chemical analyses of major inorganic constituents of ground-water samples.

STATION NUMBER	GEO-LOGIC UNIT	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO3) (MG/L)	CAR-BONATE (CO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)
413802107333101	125FRUN	76-05-06	--	12	130	53	46	2.8	439	--	280
413940107365301	--	76-04-14	--	8.6	130	80	12	3.6	446	0	290
413945107344501	125FRUN	63-07-09	150	7.1	150	80	6.9	3.0	400	0	360
413958107310001	125FRUN	75-09-15	--	13	190	64	12	2.4	563	0	380
	--	76-04-14	--	11	240	84	20	3.6	560	0	480
	--	76-04-14	--	--	--	--	--	--	--	--	--
	125FRUN	75-09-15	--	13	190	64	12	2.4	563	0	380
	--	76-04-14	--	11	240	84	20	3.6	560	0	480
	--	76-04-14	--	--	--	--	--	--	--	--	--
414025107294101	--	76-04-14	--	13	96	37	35	6.7	441	0	110
414100107323301	111ALVM	76-05-06	--	--	--	--	--	--	--	--	--
414416107325901	--	76-04-20	--	9.1	19	5.4	190	2.1	87	4	380
414658107254801	125FRUN	64-05-27	340	7.7	310	160	300	13	350	0	1700
	125FRUN	76-05-11	340	6.9	330	140	280	8.2	386	0	1600

STATION NUMBER	DATE OF SAMPLE	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED NITRITE PLUS NITRATE (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	AMMONIA NITRO-GEN (N) (MG/L)	DIS-SOLVED ORTHO PHOS-PHATE (PO4) (MG/L)	DIS-SOL-VED PHOS-PHORUS (P) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	HARD-NESS (CA,MG) (MG/L)	DIS-SOLVED BORON (B) (UG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	TEMPER-ATURE (DEG C)
413802107333101	76-05-06	8.2	.3	.01	--	--	--	--	751	540	30	--	9.5
413940107365301	76-04-14	2.7	.1	.01	.01	.04	.00	.00	783	650	0	1080	8.0
413945107344501	63-07-09	2.5	.2	--	--	--	--	--	827	700	20	1150	--
413958107310001	75-09-15	5.6	.2	.02	--	--	--	--	949	740	40	1380	9.0
	76-04-14	6.0	.1	.02	.03	.02	.00	.01	1130	950	9	1520	9.0
	76-04-14	--	--	--	--	--	--	--	--	--	--	1520	9.0
	75-09-15	5.6	.2	.02	--	--	--	--	949	740	40	1380	9.0
	76-04-14	8.0	.1	.02	.03	.02	.00	.01	1130	950	9	1520	9.0
	76-04-14	--	--	--	--	--	--	--	--	--	--	1520	9.0
414025107294101	76-04-14	4.5	.1	.12	.12	.43	.00	.00	522	390	50	810	8.0
414100107323301	76-05-06	--	--	--	--	--	--	--	--	--	--	>6000	10.0
414416107325901	76-04-20	10	.1	.03	--	--	--	--	663	70	20	1050	11.0
414658107254801	64-05-27	37	.3	--	--	--	--	--	2680	1400	90	3090	9.5
	76-05-11	31	.3	.04	--	--	--	--	2590	1400	70	3100	9.5

Table E7.--Trace-element analyses for ground-water samples.

STATION NUMBER	DATE OF SAMPLE	DIS-SOLVED ALUM-INUM (AL) (UG/L)	TOTAL ALUM-INUM (AL) (UG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS-SOLVED BERYL-LIUM (BE) (UG/L)	TOTAL BERYL-LIUM (BE) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	TOTAL CAD-MIUM (CD) (UG/L)	DIS-SOLVED CHRO-MIUM (CR) (UG/L)	TOTAL CHRO-MIUM (CR) (UG/L)
413940107365301	76-04-14	0	40	0	2	0	0	0	10	10	20
413958107310001	76-04-14	0	20	0	0	0	0	0	<10	10	10
	76-04-14	0	20	0	0	0	0	0	<10	10	10
414025107294101	76-04-14	0	20	0	0	0	0	0	<10	10	10
414658107254801	76-05-11	0	--	0	--	10	--	0	--	10	--

STATION NUMBER	DATE OF SAMPLE	DIS-SOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	TOTAL IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	TOTAL MAN-GANESE (MN) (UG/L)	DIS-SOLVED MOLYB-DENUM (MO) (UG/L)	TOTAL MOLYB-DENUM (MO) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	TOTAL NICKEL (NI) (UG/L)
413940107365301	76-04-14	0	60	34000	28000	0	100	340	380	0	1	0	<50
413958107310001	76-04-14	0	10	10000	11000	0	<100	490	510	0	1	1	50
	76-04-14	0	10	10000	11000	0	<100	490	510	0	1	1	50
414025107294101	76-04-14	2	10	1100	1200	0	<100	40	40	0	0	1	<50
414658107254801	76-05-11	1	--	5600	--	1	--	200	--	0	--	0	--

STATION NUMBER	DATE OF SAMPLE	DIS-SOLVED SELE-NIUM (SE) (UG/L)	TOTAL SELE-NIUM (SE) (UG/L)	DIS-SOLVED VANA-DIUM (V) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)
413940107365301	76-04-14	0	0	1.0	1500	1400
413958107310001	76-04-14	0	0	4.5	640	620
	76-04-14	0	0	4.5	640	620
414025107294101	76-04-14	0	0	.3	110	140
414658107254801	76-05-11	0	--	74	30	--

Table E8.--Radiochemical analyses of ground-water samples.

STATION NUMBER	DATE OF SAMPLE	DIS-SOLVED GROSS ALPHA AS U-NAT. (UG/L)	DIS-SOLVED GROSS BETA AS SR90 /Y90 (PC/L)	SUS-PENDED GROSS ALPHA AS U-NAT. (UG/L)	SUS-PENDED GROSS BETA AS SR90 /Y90 (PC/L)	DIS-SOLVED URANIUM (DIRECT FLUORO-METRIC) (PC/L)	DIS-SOLVED RA-226 (RADON METHOD) (PC/L)
413940107365301	76-04-14	<8.7	5.2	2.1	1.7	.7	.06
413958107310001	76-04-14	<16	54	.8	1.6	4.0	.27
	76-04-14	<16	54	.8	1.6	4.0	.27
414025107294101	76-04-14	<6.9	10	<.4	.4	--	.29

APPENDIX F

BIOLOGICAL RESOURCES

Antelope
Winter - Season No.2
Nov 15 - April 15

Big Game Habitat Condition
Rating Criteria

Daily Forage Requirement - 3.5lbs.

Condition Class	Vegetative Composition	Vegetative Cover	Browse Vigor	Browse Height	Soil Stability	Overall 1/ Condition
Good	"A&B" browse species (must be two or more) make up 75% or more of browse composition with "A" species at least 45%: and forbes and grass species each make up at least 15% of over-all composition.	Between 40 and 59% total, with browse between 20 and 34%	Less than 15% of "A" species severely hedged, and decadent minus seedling + young "A&B" species less than 15%	Averages 0-18 inches	Ground cover greater than 64%	Totals 12 or more with composition and cover rating Good and vigor, height and soil stability rating at least Fair
Fair	"A&B" browse species make up 50-74% of the browse composition with "A" species 15-44%; and forbe and grass species each make up 5-14% of overall composition	Between 20 and 39% or 60 and 79% total, with browse between 10 and 19%	Less than 35% of "A" species severely hedged, and decadent minus seedling + young "A&B" species less than 35%	Averages 18.1-24 inches	Ground cover 35-64%	Totals 9 or more with composition cover and vigor rating at least Fair
Poor	"A&B" browse species make up less than 50% of the browse composition; or "A" species less than 15%: or forbe or grass species less than 5% by overall composition	Between 0 and 19% or 80 and 100% total, or browse less than 10% or greater than 34%	More than 34% of "A" species severely hedged, or decadent minus seedling + young "A&B" species more than 34%	Averages more than 24 inches	Ground cover less than 35%	If Good or Fair requirements are not satisfied

1/ - The numberical values of 3, 2 and 1 are assigned to condition classes of Good, Fair, anf Poor resoectively for each determinent and sumed.

Antelope
Spring - Season No.3
April 16 - June 30

Big Game Habitat Condition
Rating Criteria

Condition Class	Vegetative Compsition	Vegetative Cover	Browse Vigor	Browse Height	Soil Stability	Overall Condition
Good	"A&B" forb species (must be 5 or more) make up 30% or more, and "A&B" grass species (must be 3 or more) make up 40% or more, and browse species make at least 15%	Between 40-59% total, with browse between 20-34%	Less than 15% of "A" species severely hedged, and decadent minus seedling + young "A&B" species less than 15%	Averages 0-18 inches	Ground cover more than 64%	Total 12 or more with composition and cover rating <u>Good</u> and vigor, height <u>and</u> soil stability rating at least <u>Fair</u>
Fair	"A&B" forb species (must be 5 or more) make up 15-29%, and "A&B" grass species (must be 2 or more) make up 20-39%, and browse species make up 5-14%	Between 20-39% or 60-79% total with browse between 10-19%	Less than 35% of "A" species severely hedged, and decadent minus seedling + young "A&B" species less than 35%	Averages 18.1-24 inches	Ground cover 35-64%	Totals 9 or more with composition, cover and vigor rating at least <u>Fair</u>
Poor	"A&B" forb species make up less than 15% or "A&B" grass species make up less than 20%; or browse species make up less than 5%	Between 0-19% or 80-100% total, or browse less than 10% or greater than 34%	More than 35% of "A" species severely hedged, or decadent minus seedling + young "A&B" species more than 34%	Averages more than 24 inches	Ground cover less than 35%	If <u>Good</u> or <u>Fair</u> requirements are not satisfied.

Antelope
Summer-Fall, Season No.4
July 1 - Nov 14

Big Game Habitat Condition
Rating Criteria

Condition Class	Vegetative Composition	Vegetative Cover	Browse Vigor	Browse Height	Soil Stability	Overall Condition
Good	Forbs at least 25% and Browse at least 15% with "A" species at least 10% and grasses at least 20%	Between 40-59% total, with browse between 20-34%	Less than 15% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 15%	Averages 0-18"	Ground Cover More than 64%	Totals 12 or more with composition and cover rating Good, and vigor, height and soil stability rating at least Fair
Fair	Forbs 15-24%, and Browse 5-14% with "A" Species 5-9% and grasses 5-19%	Between 20-39% or 60-79% total, with Browse between 10-19%	Less than 35% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 35%	Averages 18.1-24"	Ground Cover 35-64%	Totals nine or more with composition cover and vigor rating at least Fair
Poor	Forbs less than 15% or Browse less than 5% or Grasses less than 5%	Between 0-19% or 80-100% total, or Browse less than 10% or more than 34%	More than 34% of "A" species severely hedged or decadent minus seedling + young "A&B" species more than 34%	Averages more than 24"	Ground cover less than 35%	If Good or Fair requirements are not satisfied

Mule Deer
Winter - Season No. 2
Dec. 1 - March 15

Big Game Habitat Condition
Rating Criteria

Condition Class	Vegetative Composition	Vegetative Cover	Browse Vigor	Browse Height	Soil Stability	Overall Condition
Good	"A&B" browse species (must be two or more) make up 75% or more of browse composition with "A" Species at least 45%; and grass and forbs each make up at least 15% of overall composition	Browse between 20-34% (all species)	Less than 15% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 15%	More than 79% of "A&B" species less than 60" tall	Ground cover greater than 64%	Totals 12 or more, with cover and height each rating Good and composition, vigor, and soil stability rating at least Fair
Fair	"A&B" species make up 50-74% of browse composition, with "A" species 15-44%; and grass and forbs each make up 15-44% of overall composition	Browse between 10-19% or 35-59% (all species)	Less than 35% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 35%	Between 50-79% of "A&B" species less than 60" tall	Ground cover 35-64%	Total 9 or more with cover, vigor, height, and soil stability each rating at least Fair
Poor	"A&B" species make up less than 50% of browse composition, or "A" species less than 15%; or grass and forbs each make up less than 5% of overall composition	Browse between 0-9% or greater than 59% (all species)	More than 34% of "A" species severely hedged and decadent minus seedling + young "A&B" species more than 34%	Less than 50% of "A&B" species less than 60" tall	Ground cover less than 35%	If Good or Fair requirements are not satisfied

Mule Deer
Spring - Summer - Season No. 3
March 16 - Sept. 30

Big Game Habitat Condition
Rating Criteria

Condition Class	Vegetative Composition	Vegetative Cover	Browse Vigor	Browse Height	Soil Stability	Overall Condition
Good	"A&B forb species (must be 5 or more) make up 30% or more; and "A&B" grass species (must be 5 or more) make up 40% or more; and browse species make up 15% or more	Greater than 49% with forbs and grasses combined at least 20%	Less than 15% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 15%	More than 39% of "A&B" species less than 60" tall	Ground cover greater than 64%	Totals 12 or more with composition, and cover rating Good; and vigor, height, and soil stability rating at least Fair
Fair	"A&B" forb species (must be 5 or more) make up 15-29% and "A&B" grass species (must be two or more) make up 20-39%; and browse species make up 5-14%	Between 35-49%, with forbs and grasses combined between 15-19%	Less than 35% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 35%	Between 20-39% of "A&B" species less than 60" tall	Ground cover 35-64%	Total nine or more with composition, cover, and soil stability rating at least Fair
Poor	"A&B" forb species make up less than 15%, or "A&B" grass species make up less than 20% or browse species make up less than 5%	Less tnan 35%	More than 34% of "A" species severely hedged or decadent minus seedling + young "A&B" species less than 34%	Less than 20% of "A&B" soecies less than 60" tall	Ground cover less than 35%	If Good or Fair requirements are not satisfied

Oct. 1 - Nov 30

Condition Class	Vegetative Composition	Vegetative Cover	Browse Vigor	Browse Height	Soil Stability	Overall Condition
Good	Browse species make up 20% or more, with "A" species at least 10%; and forb species make up at least 25%; and grass species at least 20%	Greater than 49% with forbs and grasses combined at least 20%	Less than 15% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 15%	More than 59% of "A&B" species less than 60" tall	Ground cover greater than 64%	Totals 12 or more with composition and cover rating Good and vigor, height and soil stability rating at least Fair
Fair	Browse species make up 5-19% with "A" species between 5-9%; and forb species 15-24%; and grass species 5-19%	Between 35-49%, with forbs and grasses combined between 15-19%	Less than 35% of "A" species severely hedged and decadent minus seedling + young "A&B" species less than 35%	Between 30-59% of "A&B" species less than 60" tall	Ground cover 35-64%	Totals 9 or more with composition, cover and soil stability rating at least Fair
Poor	Browse species less than 5% or forb species less than 15% or grass species less than 5%	Less than 35%	More than 34% of "A" species severely hedged and decadent minus seedling + young "A&B" species more than 34%	Less than 30% of "A&B" species less than 60" tall	Ground cover less than 35%	If Good or Fair requirements are not satisfied

GPO 842-845

DATE DUE
